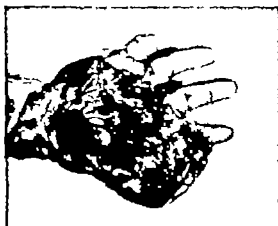
SURGERY OF REPAIR
AS APPLIED TO
HAND INJURIES



An example of the mutilating hand injuries which present from mishaps with modern industrial machinery. This hand was irretrievably pulped and devitalised in a roller press. The incident of a split second cannot be made good in a lifetime, nor can it be measured in terms of finance. The prevention of such injuries is an unqualified responsibility of every community

SURGERY OF REPAIR AS APPLIED TO HAND INJURIES

BY

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SECOND EDITION



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FOREWORD

IT is a privilege which I greatly prize to contribute a foreword to this volume, which emanates from two distinguished Australian surgeons and which must surely be in the possession of all whose concern is with injuries of the hand The thought comes readily to the mind how much the surgery of repair already owes to those whose cradle rocked or whose work has been wrought in lands under the Southern Cross. This work is no strange plant springing from an unknown soil tended by men lacking contact with the motherland its roots are veritably British for the authors have derived much of their inspiration and received training from surgeons like Gillies McIndoe, Kilner and Rainsford Mowlem. It may therefore be reckoned a British Empire work embodying all that has made British reparative surgery famous throughout the world as well as the special experience which has come the authors way

The writers are not fickle protagonists of the view that the reparative surgery of the damaged hand is the peculiar province of the plastic surgeon This field of surgery has been a no man s land which has provided no compelling attraction for rival surgical specialties, but which has been gladly assigned by colleagues to those most fitted by temperament and surgical training to produce the best results These two authors have been fortunate in the abundance and the length of their experience, which embraces injuries of the hand of industrial and war causation seen in civilian, military and repatriation hospitals, and which therefore sets an authoritative seal on this work

True to their beliefs and notwithstanding their seniority the authors have been ready at all times to answer the call for skilled surgical assistance in cases of hand injury *In utrumque paratus* as the Fourth Fytte of Adam Lindsay Gordon s Ye Wearie Wayfarer would have it, or assuming the devoted attitude of the most consummate representative of the maieutic art. By their altruistic outlook and conduct they have secured the good results described and depicted in this book.

Those whose function it is to deal with injuries of the hand will derive much profit and valuable assistance from those parts of the book drawing attention to what might be termed ' a new anatomy of the hand it is of interest to the scholar as well as the surgeon.

In conclusion no reader of this work can fail to realise the impact of repair minded surgery on the progress and advance of the science and art of Surgery itself

Gordon Gordon-Taylor

LONDON,
1953

PREFACE TO SECOND EDITION

IN preparing a second edition of this book only a few years after writing it, we have not felt compelled to make radical changes The general format remains the same. A few modifications and amplifications of detail and method have been indicated by further experience. We have also elaborated on certain points as suggested by many kind readers who have taken the trouble to write to us It seems that the general cross-section of surgeons make the best proof readers, and we are very grateful to all these men

We have resisted, too the temptation and repeated suggestion that we extend the subject beyond the confines of the title to other ramifications of hand surgery That would only diverge from our objective which is to draw attention to the obligations of surgeons towards the challenge presented by the ever increasing range of hand injuries.

We have added some new illustrations and replaced others

Dr Lennard Travers who has helped us with all our anæsthetic problems over many years, has assisted to bring the section on anæsthesia up to date We also record the valuable help of Mr Clifford Wellington over the years. He has provided the many prosthetic and mechanical devices we seek often at short notice. This is an essential form of service where any volume of this work is done.

We have had no cause whatever to vary our praise and admiration of the helpful attitude of our publishers

B K. RANK.
A R WAKEFIELD

MELBOURNE,
1960.

PREFACE TO FIRST EDITION

INJURIES to the hand constitute a special problem for the surgeons of any modern community Against wider horizons of modern surgical endeavour there is always a sobering thought in the high standards of structural exactitude required to subserve the many perfections of simplicity and intricacy which make up the normal functioning unit of a human hand. To contribute in some measure to the natural restoration of a hand from the unnatural effects which beset individuals to-day offers unique stimulus, scope and prize to the art of surgery and to the craft of surgeons

The valued principles of the surgery of injury are well exemplified in their application to injured hands. Their careful application could not be more rewarded nor their disregard more conspicuous than in this particular application Principles may not change, but neither is surgery static, for the method of application or the emphasis on principles does change.

We have set out to write a book on the surgery of hand injuries under present-day conditions, where the indications and possibilities of modern

reparative surgery call for reiteration of certain principles and for realisation of higher standards of technical achievement. The prize of modern reparative surgery is often high, but so is its price, and without the precise technical knowledge and practice of how to achieve a certain end it might well often be in the patient's interest if we returned to the era of secondary closure of traumatic wounds

We have not set out to record in familiar fashion known facts, accepted opinions and methods of treatment under various arbitrary headings to which the title might well be dissected. Our object has been to record the more fruitful developments of personal opportunity unembarrassed by consideration of alternative procedures. We realise full well that there are diverse paths to successful accomplishment, but these are generally in matters of detail or personal interpretation of values and not in matters of principle We accept any criticism of incompleteness, believing it better to remain incomplete as a reference book than to transgress beyond the scope of first hand experience. Nor do we see reason to reduplicate much that has been well covered by others in relation to closed injuries and fractures for our experience has been in the main with open injuries

The work is meant primarily for the discriminative interest of those who see and treat hand injuries With a few deliberate exceptions we have refrained from basic descriptions of elementary operative procedures which every well trained surgeon of injury must know to-day Our concern is rather with the correct and timely application of these procedures.

We have endeavoured to arrange the presentation in relation to injuries as they occur Anatomical systematisation leads to hypothetical consideration of many injuries which might arise but it loses emphasis on reality

It is frequently stated that true experience is only accumulated by personal trials and errors We hope to contribute to the interest of hand mutilees by some easing of this method and to the ultimate accomplishment of younger surgeons by some sparing of the timidity and uncertainty by which we have tediously developed our own standards That surgery is not static is due, at least in some measure, to the fact that each newcomer has opportunity to start with a reduced lag in accumulated knowledge to achieve new standards

With great respect we fully acknowledge the teaching and generously recorded experience of the men who have largely activated our own thought and practice in the sphere of hand injuries. Sir Harold Gillies, Sterling Bunnell and Sumner Koch have indeed, been our main inspiration—Gillies, the founder of a technique the value of which well continues to be realised in its extending application Bunnell and Koch who have shown the possibilities of reparative surgery of the hand We have also derived inestimable help from our friendly association with their many disciples the world over men of our own generation too numerous to list. Some of them are mentioned in the text where opportune, but we have purposely avoided full lists of reference work beyond those of direct concern to our immediate purpose.

We acknowledge with gratitude our personal debt to the beneficence of the Carnegie Corporation in the United States of America, the Nuffield

Foundation in Great Britain and the Australian Red Cross Society Each of these, through the National Health and Medical Research Council of Australia, have given us opportunity to see and study this work in Britain and America in the light of our own difficulties and problems We hope that their trust and gesture have not been wasted

Various reasons have prompted this work First, it is obligatory on any who have had peculiar opportunity in a particular branch of surgery to record the value of that experience at some appropriate time More especially does this apply if, as in our case, such opportunity has largely been possible as the result of the broader and impersonal vision of such a large number of our colleagues Our early interest in hand injury and perhaps some demonstration of improved results, has signalled a snowballing of opportunity

The book is based on work done in the past ten years when a large portion of our time has been spent in the care of patients with injured hands of all types and in diverse stages In the first half of this period, as a result of the policy of the Medical Directorate of the Australian Army Medical Corps a large number of men with injured hands was concentrated under our care in an Army Plastic Surgery Unit During this phase we experienced much of the many hazards associated with secondary repair in the wake of infection, long immobilisation fibrosis and joint stiffness. Under these conditions reparative procedures were often attempted in ambitious fashion for some slight improvement in the function of a hand remnant. We would like to record the early encouragement and help we received from the late Brigadier W A Hailes and from Colonel C W B Littlejohn Consultant Surgeons to the Australian Army during this period when we were the instruments of their policy

In the latter half of this ten-year period, at various hospitals in the city of Melbourne we have had ample opportunity for the primary and continued treatment of recent hand injuries under circumstances impossible in arrangements of war With the undoubted advantage of antibiotic drugs we have been able to apply primary reparative procedures with vastly improved economy and value to all concerned It is the scope and place of these which constitute our main message

Plastic or reconstructive surgery is variously considered as an arbitrary subdivision of surgical practice, but it is none other than a method or technique of surgery Its scope is wherever this can be applied with value. We do not pretend that the management of hand injuries is the exclusive sphere of any particular sect or group In centres the world over hand injuries are concentrated and managed under diverse arrangements with equivalent results We would categorically state, however, that the best can only be achieved where organisation permits of continuity of management by surgeons fully versed in the technique and application of plastic surgery and we fail to see how this can be developed in any strictly regional manner within the confines of the hand Any surgeon who deals with hand injuries must also be schooled in orthopædic procedures relative to injury and in peripheral nerve surgery There must be some reshuffle in surgical organisation to include surgeons of injury and repair fully trained in these matters, and we are in full accord with the

precept and example of Mr W G Gissane in Birmingham It is a pity however, that the term traumatic surgery" is sometimes used for such work when indeed, its password should be atraumatic surgery

Some excellent writings are available which deal largely with secondary reparative procedure and with septic conditions of the hand. Under present-day conditions, however, we feel these aspects are over-emphasised at the expense of a more detailed concern with primary treatment of injury If primary treatment is all that it should and can be, there is a fast-diminishing need for secondary reparative procedures and infective complications become an increasing rarity

Some separate attention has been given to hand injuries in children (Chapter XVII) so that certain common features of injury and repair in children can be underlined This must not detract from the necessity for tempering any observation opinion or management with the age or youth of the patient The capacity of the young to heal remodel and adapt is only believable to those familiar with the surgical care of children No single general factor has a more pervading and profound influence on prognosis. Statements or claims which are not considered in this light by both reader and writer will cause much misconception in the management of hand injuries

In the preparation of the book we have had much help from many kind people First, our own immediate professional associates and staff especially the nursing sisters and physiotherapists secondly our colleagues who have made possible our concentration of experience and thirdly those who have worked in direct preparation of the book itself—Mrs W A. Scott and Miss J Boyd our typists, Olive and Joe Roach, Mr Roy Ingles and Helen Wischewsen who have been variously responsible for the illustrations. All have been patient and long suffering.

Professor Sydney Sunderland has been long and happily associated in the anatomical and neurological aspects of our work and has advised us in the anatomical presentation

We have been fortunate to have as proof readers Mr R. Guy Pulvertaft of Derby and Mr A B Wallace of Edinburgh. We have valued their constructive criticism.

We hold the warmest regard for Mr C Macmillan and Mr J Parker Directors of E. & S Livingstone Ltd The negotiations and smooth conduct of publishing, despite our separation by twelve thousand miles, would have been impossible without their help and co-operation throughout.

That our beloved mentor and champion of British Surgery throughout the Empire, Surgeon Rear Admiral Sir Gordon Gordon-Taylor should compile the foreword we take as a signal honour

B K. RANK.
A. R. WAKEFIELD

MELBOURNE,
1953

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GENERAL

CHAPTER I

THE SOCIAL SIGNIFICANCE OF HAND INJURIES

THE INCIDENCE OF HAND INJURIES AND HOW THEY OCCUR

APPROXIMATELY one in every three of the injuries which present to the casualty department of a metropolitan general hospital involves the hand. This high everyday incidence of hand injuries merits critical examination

The source of hand injuries differs from that of accidents in general (Fig. 1) Accidents in industry are their dominant cause. Approximately one third of the general factory accident rate concerns the hand but the

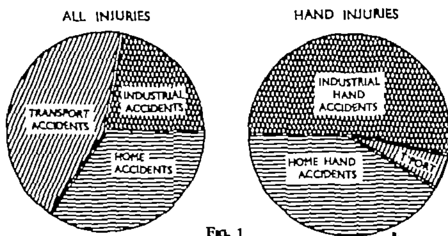


FIG. 1

The source of hand injuries

The relative proportions in these diagrams are based on a recent yearly analysis of all injuries presenting to the Casualty Department of the Royal Melbourne Hospital, approximately 13 000 per year

proportion varies in different industries (Fig. 2) Such is the diversity of accident laws and regulations in various states and in various countries that any comparative study of figures is futile without a full appraisal of relevant legislation An accident may be notifiable in one country and not in another

Figures[1] studied from the first year of working of the National Health and Insurance Act in Great Britain (1949) emphasise the magnitude of the problem Of approximately 737 500 injury benefits for accidents and prescribed diseases during employment, 211,280 were paid to persons with hand injuries, *i.e* approximately one in three. Of 6 656 000 benefits for accidents and illness

[1] We gratefully acknowledge the kind personal help of Dr Edith Summerskill (then Minister of National Insurance) in obtaining this detailed information, and also the patience of her staff responsible for dissection and detailed breakdown of the figures.

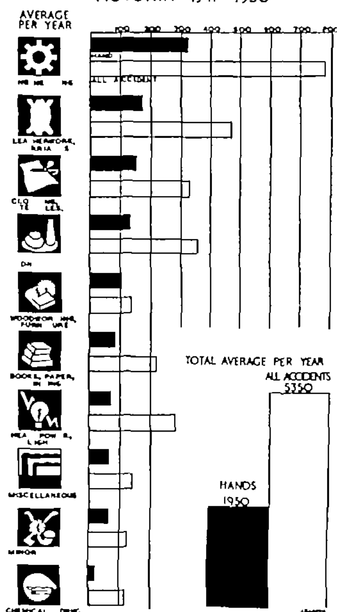


FIG 2

Hand Injuries in Industry

The proportion of accidents which involve the hand in various industries in the State of Victoria is set out This is based on a yearly average, over a ten-year period 1940-50, of figures given in Victorian Government Department of Labour Annual Reports. Only those industries of relative local significance as a cause of hand injuries are included. It should be realised that heavy industries such as shipbuilding and mining are insignificant in this State They would be a prominent source of accidents in other countries. In Victoria, a factory as registered under the Factories Act is any establishment which employs four persons in handicraft, trade, or sale, or which employs only one person if half a horse power is also employed. The State Law is that any accident which keeps a man off work for one shift or for twenty-four hours must be reported.

outside employment, only 124 680 were for hand injuries, *i e* approximately one in fifty These figures cover the insured population of Great Britain which broadly corresponds to the working population approximately 24 million As a result of a recent investigation in Britain Ruth Wilkes[1] notes that " in 1951 the annual cost to the country in injury benefit paid for hand injuries was approximately £2 2 million

CAUSE OF SEVERE HAND INJURIES

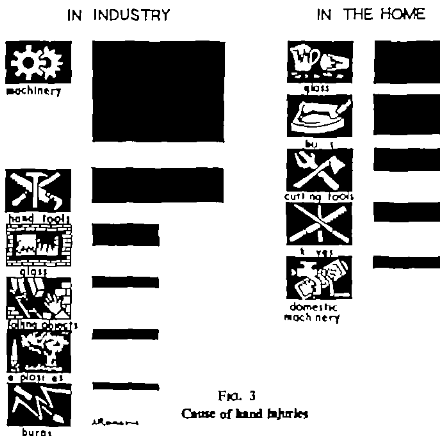


Fig. 3
Cause of hand injuries

This diagram indicates the common causes of approximately 1,000 cases of hand injuries which involved hospital admission. These are the more severe injuries, which explains the high proportion due to machinery The black masses indicate relative proportions.

Statistics published annually by the United States Department of Labour indicate that of approximately 2 million disabling work injuries which occur in that country each year three-quarters involve some permanent impairment of hand function In some industries hand injuries account for more than 90 per cent. of the disabling injuries reported[2] (metal furniture, 96 per cent stamped and pressed metal products, 91 per cent. miscellaneous manufacturing 93 per cent. slaughtering and meat packing, 90 per cent.)

[1] Wilkes, R. (1956). A social and occupational study of injured hands. *Brit J Industr Med* 13 119

[2] Work Injuries in the United States during 1948 *Bulletin* 975 U.S. Department of Labour

It is a fact of curious significance that while industry is the main source of hand injuries, and while it would seem obvious and easy to attribute this to mechanisation 60 per cent. of all hand injuries which occur in industry are not due to the agent of machinery Most of the more severe hand injuries, however are among the 40 per cent. caused by machinery (Fig. 3) The majority of industrial accidents are due to personal factors—stepping or striking against objects, falls, cuts or handling of materials without machinery They occur in the same way as do common household injuries. These "household type" accidents have been the subject of much research and planning in industry for physical, mental and social conditions of the individual are often important factors in their causation Research has shown their relation to age, experience, responsibility and general health of the employee, and to factory conditions of hours fatigue atmosphere and lighting. Furthermore, there are "accident prone individuals, for the numbers who receive multiple and repeated injuries are out of all proportion to chance conditions. Evidence of previous hand injury from similar or other causes is often noted where large numbers of industrial injuries are handled Many attempts to investigate this matter have been fruitless because relevant data have proved so complex In prevention therefore it would seem more profitable to investigate conditions giving rise to accidents in average people, rather than to pick out and endeavour to analyse unfortunate individuals who are accident prone."

Home accidents constitute the only other significant source of hand injuries These injuries are rarely severe Their more common causes are also indicated in Fig 3 Each new household innovation or mechanical gadget, from bean slicer to pressure cooker brings its train of peculiar lesions. It is unfortunate that safety construction and legislation too often come after a period of trial and error rather than as a result of any prior exhaustive inquiry trial and approval A certain type of household radiator has brought disaster to many children s hands, and yet legislation directed to prevent the marketing of such unguarded hazards is still in the stage of controversy It is noteworthy how these mishaps occur in the poorer household which is forced to the cheaper market

ECONOMIC CONSIDERATIONS OF HAND INJURIES

Extremely few hand injuries result in death but they cause untold loss to the injured his family his employer and his fellow-citizens.

Estimates in various countries indicate that approximately 20 per cent of huge total compensation payments are for hand injuries. In the United States, in the year 1950[1] the direct compensation paid for approximately 515 000 hand and/or finger injuries was $141 625 000 In addition to monetary payment for medical care and compensation there are intangible costs on many scores, such as loss of man hours, ir[illegible] and t[illegible] of skilled effectives. It is generally consider[illegible] hidden [illegible]ly such

[1] From the Statistical Division, National [illegible] America, [illegible]ication 1951

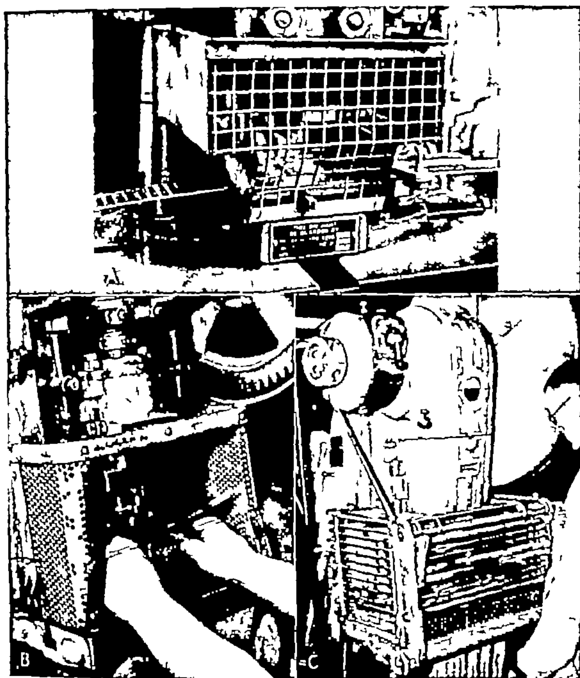


Fig. 4

Safety devices on power presses to prevent hand injuries

A, Fixed guard. Systematic approach to machine guarding is indicated by the metal tag riveted to the die. This firm has about twenty-five power presses and fifteen hundred dies. All pressing operations are effectively protected by three standard designs of guard. Every guard is stamped with a number and every die carries a metal tag indicating the number of the guard to be used.

B, Another type of fixed guard. A perspex window allows good visibility to the machine, a bent plate mounted inside the guard prevents the hand reaching the danger zone while side feeding strip metal

C, An automatic guard. In this case an automatic control closes the shutter in front of the guard before the stroke begins, keeps it closed during the stroke and opens it when the stroke ends. With any obstruction to closing, the machine will not operate.

(Photography by courtesy of Commonwealth Department of Labour.)

figures of direct payments as set out four or five times In a young country like Australia endeavouring to build up population when immigration is such a costly and difficult undertaking, the loss of such a valued asset as a skilled worker cannot reasonably be estimated

Still further personal hardship and misery are caused to the uninsured victims of hand injury What of the housewife and mother who in a split second accident of her household chores suffers long crippling from injured tendons and nerves? What of the husband father and breadwinner who in alcoholic aberration puts his fist through a window or falls with a broken beer bottle? His plight is indeed a pathetic one The exasperation of the surgeon committed to the long tedium of his management is soon mellowed by thought of the tragic hardship to a family

Accident prevention is a community and State responsibility of the highest order This has been increasingly realised since 1911 when British compensation laws first commenced to absolve the need for a worker to suffer or else fight his own loss in civil action for negligence against his employer

In recent years National Safety Councils and Government Labour Departments have been increasingly active and effective in reducing the number of industrial injuries Prevention of accidents requires full understanding and research into their reasons and basic causes The inception and policing of high standards of accident reporting have contributed most to this end The objective now is to determine why accidents happen and not merely how they happen The medical profession has some responsibility to contribute to accident prevention It can help by keeping designers employers and public informed on recurrent patterns of injury and how they may be caused by mechanical devices, old and new

Two examples illustrate how this can apply —

1 A small number of metal polishers came under our care with severe "brush burns" of the hand—men from different workshops but injured in precisely the same manner Each was using a small size buff in the corner of a metal tray when in an instant the buff jumped out of control and caught in the open wrist cuff of his glove to run up into the palm, causing typical and bad friction burns They told of workmates injured in the same way Such accumulated information serves the most useful function of medical practice—prevention Metal polishers should all wear a close fitting elastic or woollen cuff about the open ends of their gloves

2. We have recently noted a disproportionate number of new Australian migrants with severe types of hand mutilation as a result of power press injuries. These are typical injuries in people of typical make-up and background Most have been middle-aged men and women who in Europe, served occupations of the "white-collar" type such as office work or school teaching. Soon after arrival in their new country they have been taken into industry to work at machinery in a new vocation quite foreign to their previous livelihood Two injuries of a type illustrated in Fig. 5 were caused by the same machine within a week the one man taking the other man s place at the machine and following him to hospital too What sad loss to the individuals and to the country!

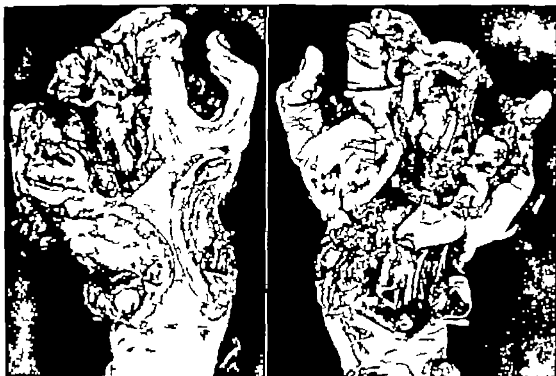


Fig 5

A gross hand injury suffered by a person not used to machinery soon after commencing work on a plastic moulding press (300° C.) Amputation was necessary The injury shown *in Fig. 97 was caused by the same machine within a few weeks.*

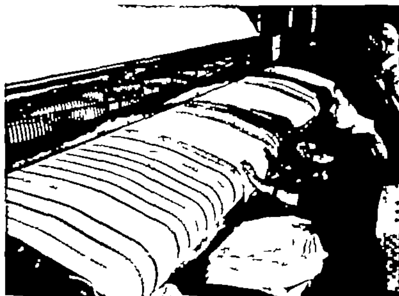


Fig. 6

Laundry ironing machine

The safety barrier is designed so that if the operator s hand strikes it, electrical power is cut off the machine is braked rapidly and the hot bed is lowered to prevent hands being caught and burnt.

The lesson surely is that people cannot become machine-conscious overnight or by edict

The cost of vocation selection trial and training to prevent " square pegs " being placed into " round holes without reference to the specific requirements of any new job is minute when compared with the needless waste and suffering depicted

The American Standards Association [1] has developed a standard method of accident reporting adapted to the purpose of accident prevention It is now widely used in most of the States It recognises six major groups of accident factors as follows (1) The agency (*i e* the defective object or substance most closely related to the injury) (2) the agency part (3) the unsafe mechanical or physical condition (4) the accident type (5) the unsafe act (6) the unsafe personal factor Detailed code numbers are developed to these headings.

Despite the best and universal use of accident prevention methods there must always be an irreducible minimum of accidents which represent mechanical imperfection of machines and personal imperfections of individuals Machinery protection can be provided to the full practical limit, and there is no end to design and materials used in gloves for workers in relation to specific purposes but though mechanical hazards are so reduced their effective use depends on the safety consciousness and responsibility of individuals. Most hand injuries occur at the point of contact of materials with the machinery and the majority of them are due to unsafe acts by the individual especially when his attention wanders or is distracted Circular saws power presses and buzz planes are common causes of such injuries

PERSONAL AND INDIVIDUAL ASPECTS OF HAND INJURY

These may be far reaching in severe cases Personal loss cannot always be translated into standard financial arrangements This explains why many injured people become embittered and labour under the delusion that they have been badly treated in any standardised compensation arrangement

The effects of long enforced illness and idleness, long-delayed or protracted litigation or the common state of compensation mindedness if not purposefully prevented or managed may induce personality changes of a type previously foreign to the person concerned A happy and well adapted man—a social asset—may become a disgruntled member trying alike to his family friends, employers and medical advisers Loss of confidence and a shelter seeking personality are common psychological repercussions of severe accidental hand injuries Change in occupation enforced by circumstances of injury requires a careful and purposeful adjustment of which not everyone is capable It is not easy for a man trained and at heart a mechanic to be deprived of the value of his time-earned manual experience and personal aptitude

[1] *American Standards Association* Z16, 2, 1941 Parts 1 and 2.

MEDICAL RESPONSIBILITY CONCERNING HAND INJURIES

Medical care of patients with injured hands must extend well beyond the confines of its particular concern with healing and restoration of anatomy and function It must also include long term personal and economic considerations. Good practice for one can well be misguided in its application to another A saw miller would be better off with an amputated finger if he could return to his saw milling than he would be if time-consuming anatomical restoration of the injured finger were conducted with a fine but fragile result which prevented the resumption of his normal job Surgical idealism may or may not be best for the patient.

The particular secondary viewpoints of medical man employer and insurer may be at variance The surgeon is more concerned in the finesse of structural repair The employer is interested in the man s early return to his old job and not his employment in some lesser direction The insurer s attention is focused on his overall financial obligation All, however have a primary common interest in the injured man receiving the best possible result in the shortest possible time Nothing is more basic to their common objective than the highest standards of primary management of hand injuries A conflict of secondary interests arises rather in the long term cases with severe disabilities of months duration when tedious secondary procedures are called for many of which can be prevented by primary treatment under the best conditions If this is realised, all parties must give way in their particular secondary concern to the welfare interest of the patient. It is essential that the surgeon remain a free agent with an unfettered doctor patient relationship He must certainly collaborate with employer and insurer but should be subservient to neither

CHAPTER II

SURGICAL ANATOMY OF THE HAND

THIS chapter on the surgical anatomy of the hand has been included primarily to stress a changed emphasis on various aspects of the subject which must be fully appreciated by all who venture into the field of hand surgery

Although there have been many brilliant surgeon-anatomists, it is fair comment that most surgeons can retain constantly in their minds only a limited amount of the infinite detail of anatomy—that which is pertinent to their daily activities as surgeons It is clear that with changes in the scope and range of surgery the surgeon s knowledge of relevant anatomy must be kept thoroughly up to date. The surgery of the hand is one of the best of many examples where this consideration applies.

It is a very few years since hand surgery was dominated by infection Infection dictated clinical teaching and anatomical research and if a student came to his examinations with a knowledge of the various types of hand sepsis and their associated anatomy he felt safe in the knowledge that there was little else of importance that he might be asked in this field If he knew Kanavel's[1] teaching he could hardly go wrong.

The emphasis is now changed. Major hand sepsis has become a comparative rarity, and thought must now be focused on anatomy as related to repair and reconstruction rather than sepsis and destruction A sound knowledge of recognised fascial spaces and tendon sheaths and of the classical distribution of major vessels and nerves will not suffice. We are now concerned with the anatomy of function and not the pathological distortions of sepsis. We are less concerned where pus tracks and accumulates or in which arbitrary fascial space a tendon may lie. We are more concerned with the size, shape, length detailed attachments, excursions during movement synovial reflections and many other intimate details relating to the tendon itself and which determine how it functions So too we are not so much concerned with how incisions should be placed to establish drainage as with how they should be placed to provide proper exposure and yet minimise the effects of scar contracture.

Along with this there has been increased opportunity for the study of detailed anatomy in the living subject. This has resulted from the widespread use of the tourniquet to produce a clear avascular field for dissection at the many operations which are now carried out on the hand most of them reparative in object. Under these circumstances many anatomical minutiae can be observed in a manner impossible at cadaver dissection Many such details have received no emphasis in the past, and although they are doubtless familiar to academic anatomists their significance has not been appreciated in relation to surgical practice

All this, however is of little practical value without familiarity—without an almost subconscious recognition of structures, what they look like and how

[1] Kanavel (1933). *Infections of the Hand* Philadelphia Lea & Febiger

they feel. It is only such familiarity which prevents strands of fascia from being identified as nerves tendon sheaths from being repaired " instead of the tendons themselves, the blissful section of digital nerves or even confusion between the median nerve and a flexor tendon when both are divided at the wrist

POSTURE OF THE HAND

Perhaps the most important conception in hand surgery is that of the " position of rest [1] (Fig. 7)—the relaxed position taken up by the hand at rest



Fig 7
The position of rest.



Fig 8
The effect of wrist posture on finger flexion at rest.

with its neuromuscular mechanism in a state of balanced tone The posture of the normal relaxed hand can very well be studied on a subject whilst asleep or lightly anæsthetised When the wrist is slightly flexed the thumb tip is close

[1] Wood, Jones (1949). *Principles of Anatomy as seen in the Hand* p 149 London Baillière, Tindall & Cox.

beside the distal interphalangeal joint of the index finger Each finger lies in an obvious typical and clearly graded sequence of partial flexion ranging in degree *from the thumb to the little finger The tip of the index finger is inclined towards* the ulnar side and that of the little finger towards the radial side of the hand.

The influence of wrist position on this posture should be noted By passive flexion and extension of the wrist the degree of flexion in each finger is altered but its relation to neighbouring fingers remains the same (Fig. 8)

Proper understanding of the position of rest and its normal variation with changes in wrist posture is basic in diagnosis of injury as it is in treatment In diagnosis it is often not appreciated, in treatment too often forgotten. It is a simple matter of clinical observation to note any departure from the normal posture when it is upset by injury to any portion of the neuromuscular mechanism which controls it Examples of this will be detailed in Chapter IV It is in this position that most fractures are stable when reduced it is in this position and no other, that the fingers can be immobilised for relatively long periods without prejudice to ultimate joint function

HAND TYPES AND NORMAL VARIATIONS

In the course of many examinations and operations for injured hands over a period of years one comes to recognise a variety of hand types. These can often be associated not only with certain classes of injury but also with the *choice of surgical procedure and with the order of result that can be anticipated*

Broadly there are three groups. The first may be termed the average hand. It is the hand of the man who lives by his wits, and is differentiated neither for power and durability nor for any particular degree of finesse or dexterity It is used no more than is necessary for personal convenience and is injured only when called on for some unusual effort to which it has not been trained

The second group belongs to those who daily use their hands in moderate to heavy work and who live by such work Here sustained power and stability in the performance of a few simple movements together with durability of the surface skin are paramount. A thick horny surface layer and powerful mass hand movements are developed at the expense of finger tip sensibility and the intricate and independent movements of individual fingers

The third group comprises those hands which are constantly used for highly skilled work, often involving sensitive finger tip control and delicate independent finger movements The musician or perhaps even the surgeon may be among the best examples of this class. Such people learn to care for their hands and do not frequently injure them When they do however the results are more tragic and a much higher order of functional recovery is necessary to restore them to their special work

Although there is an increasing group of mechanics and engineers in whose hands are combined many of the characteristics of the second and third groups, it is nevertheless extremely useful to think along these lines in the management of injury Such thought will often make for a better choice of procedure and will enable a more accurate prognosis to be given It serves also to bring home

the wide variations in the normal range of joint movements and in the degree of independence in finger function The variation in the range of the interphalangeal joints is a case in point Flexion of the thick, heavy skinned finger of the labourer to the horny palm involves less range at the metacarpo-phalangeal and interphalangeal joints than does the same movement in the slender thin skinned hand Even the degree of active flexion that is possible at the distal joints is variable and in manual workers may be extremely limited (Fig. 9)

A proper appreciation of the range of normality in regard to these and

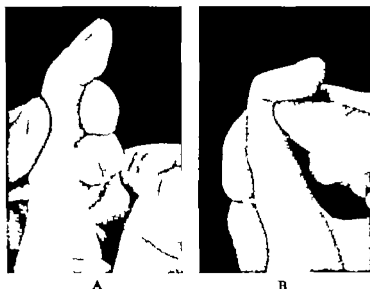


FIG 9

Normal variations in joint range

A, Limited flexion range at the distal interphalangeal joint in a labourer's hand. B Range of flexion in a skilled worker

other variants is essential not only in the choice of the correct procedure for any particular case but in assessing results of surgery which cannot be measured by any numerical yardstick common to all

THE SKIN

The skin of the palm shows many variations adapted to its peculiar importance. Its thick cornified layer and its fibrous connections with the deep fascia make it rigid and inelastic when compared with that on the dorsum and elsewhere. It is more than well supplied with sweat glands It is capable of increasing or decreasing the thickness of its horny layer in response to functional demands.

These factors have considerable bearing in relation to wounds and their healing. Union does not occur across the surface horny layer which peels off from suture lines and their surroundings several weeks after operation or earlier if allowed to become moist or infected The relative inelasticity of the skin does not allow of any tension in wound closure and militates against the

design of any local flaps to meet conditions of skin loss From this it can be seen that only very little skin loss can be made good from the skin of the palm itself and even minor losses will become apparent in functional limitation Furthermore, the differentiation of palmar skin means that it cannot be truly replaced from any other less important part of the body No matter what other skin we may use for this purpose, it never has and never acquires those special properties

In contrast the skin of the dorsum is thin mobile and elastic—characteristics which are used to their limit when the fingers and thumb are fully flexed in the clenched fist That there is just enough dorsal skin to allow of full flexion of the fingers is apparent when the clenched fist is examined. The skin over the knuckles is tight and blanched by the tension as it is stretched to the limit of elasticity Just as on the palm, therefore, even minor degrees of skin loss make themselves apparent by limitation of function Even second degree burns of the dorsum for example which heal spontaneously and quickly and which are associated when healed with diffuse and microscopic intracutaneous scarring, leave their mark of limitation of full finger flexion Whilst this may improve with time, it is only at the cost of dragging the forearm skin down towards the hand pulling the finger skin back from the nail beds and stretching the marginal skin round on to the dorsum

THE NAILS

Distortions and growth irregularities of finger nails are a common result of direct injury to the nail but may also occur secondarily to any condition such as infection or scar retraction which causes exposure of the growing nail base

Nail bed extends from the point of insertion of the extensor tendon into the distal phalanx to a point a little proximal to the finger tip and laterally it extends far round the sides of the phalanx to the mid-coronal plane. Failure to appreciate the extent of the base of the nail bed is often responsible for its incomplete removal and the re growth of nail fragments in amputation stumps

There is no distinction between nail bed and periosteum over the back of the terminal phalanx and injuries or operations involving loss of nail and nail bed leave the cortical bone of the phalanx exposed This generally necessitates either covering the exposed area with a flap or an amputation of the finger tip

It takes very little disturbance of the nail bed to produce an upset in nail growth Loss of terminal finger pulp often with loss of the tip of the phalanx, if allowed to heal by scar causes a curving of the nail growth over the end of the bone This may be difficult to trim and control

Damage to the terminal portion of the nail bed may cause the nail to grow away from the finger end and be easily broken and torn

Retraction of the skin which normally covers the proximal third of the nail bed as invariably occurs after burns of any severity to the dorsum of the fingers, is followed by onychogryphosis of a severity dependent on the degree of exposure of the nail base

THE SUBCUTANEOUS TISSUE

On the flexor surface of the hand this consists of a layer of granular fatty tissue which is subdivided into compartments by fibrous septa. These anchor the surface skin to the well-developed palmar aponeurosis and the fascial sheaths of the fingers. This fatty tissue is deficient under the flexion creases and over the thenar eminence.

The subcutaneous tissue on the dorsum, however, contains little fat. It consists of a thin layer of loose areolar tissue separating the skin from the extensor tendons and their synovial covering, permitting free mobility of the skin over deep structures. Because of this loose attachment, the dorsal skin is easily avulsed when caught up in the machines of modern industry.

THE FASCIA

This has been extensively covered in other works and has received more recent attention by Jamieson.[1] It is of little importance in relation to injury and repair and we do not propose to elaborate on it here.

It may, however, be pertinent to mention that changes clinically identical with those of Dupuytren's contracture are not uncommonly precipitated by injury. We have noted this most commonly in middle aged people whose fingers are immobilised for any reason. It is surely more than coincidence that we have observed these changes following immobilisation for tendon injuries, fractures, sepsis and a variety of other surgical conditions which may or may not be localised within the hand itself.

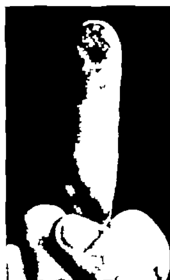


FIG. 10

Trophic ulcer on anæsthetic finger

Both neurovascular bundles were severed as well as the flexor tendons. The poor collateral circulation following section of both main digital vessels plays no small part in the origin and indolence of these lesions.

THE BLOOD-VESSELS

The close relation between the main blood vessels and the nerves to the fingers deserves emphasis. This close association means that, in cutting injuries where one is divided the other is usually also divided and it may be that some of the so-called trophic changes associated with division of these nerves are at least in part due to direct damage to the adjacent blood vessels and the sympathetic fibres related to them (Fig. 10). The same proximity of nerves and vessels also means that nerves can easily be severely damaged by the indiscriminate use of artery forceps to control bleeding in first aid centres and casualty departments.

[1] Jamieson, J. Gardner (1950-51). The fascial spaces of the palm. *Brit. J. Surg.* 38, 190.

When one of the two main digital arteries remains intact in injuries to the fingers there is never any doubt about the viability of the finger. When both vessels are divided or otherwise damaged as in the case of electric burns the peripheral finger circulation is always sluggish, and if there is at the same time much soft tissue and bony damage peripheral gangrene is common. The integrity of the neurovascular bundles has much bearing on decisions relating to primary finger amputations. Even if a doubtful finger survives the collateral circulation may remain sluggish and contribute to subsequent trophic changes. Injury to any of the major vessels proximal to the fingers rarely gives rise to doubts about viability except where soft tissue damage is circumferential. Section of both radial and ulnar arteries on the front of the wrist is not uncommon in cutting injuries and the collateral circulation is always adequate.

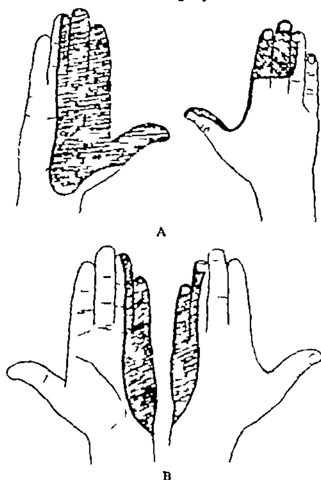


Fig. 11

The usual patterns of anæsthesia resulting from lesions of A median nerve, B, ulnar nerve

(Stopford Journal of Anatomy Vol 53)

THE NERVES

The classical cutaneous distribution of the three main nerves concerned in the sensory supply of the hand and the pattern of anæsthesia that results from their injury are well known (Fig. 11 A and B). It is necessary to stress only a few points of practical importance.

The classical description does not always prevail and variations in the peripheral distribution of the median and ulnar nerves are of particular clinical significance. It sometimes happens that the ulnar nerve *carries more fibres and the median less* and under these circumstances section of one or the other will produce an unusual pattern of anæsthesia which may appear confusing unless the state of affairs is realised. The common variations are seen when the ulnar supplies two or two and a half digits instead of one and a half (Fig. 12, A and B).

It is of some importance to remember that the dorsal branch of the ulnar nerve is given off and passes dorsally well above the wrist level. It is therefore generally spared when the ulnar nerve is divided at the wrist. For this reason

it is common in the course of clinical examination to have the patient react to a stimulus which is carelessly applied along the side of the hand and little finger

Sparing of the palmar cutaneous branches of the median and ulnar nerves may also cause confusion, although the common injuries usually involve these as well as the main trunks

The part played by the radial nerve in the sensory innervation of the hand is variable and of little importance to surgery Even its complete division leaves only a small area of absolute anæsthesia on the dorsum in a region where such loss is insignificant In any case the nerve has already divided into a number of peripheral branches, and it is unusual for all of these to be cut in cases of injury at the wrist or in the hand

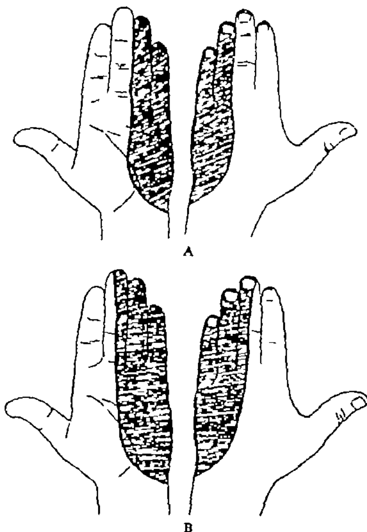


Fig 12

Common variations in the sensory distribution of the ulnar nerve

A is more common than B.

(*Stopford—Journal of Anatomy Vol. 53.*)

It is quite extraordinary how unreliable we can all be in estimating whether a major nerve is or is not involved in any injured hand. The fault invariably can be traced either to quickly forgotten anatomy or to slipshod methods of clinical examination

On the motor side a similar reciprocal variation can also occur in the distribution of the two main nerves This concerns the innervation of the lumbrical muscles, the first dorsal interosseous and the intrinsic muscles of the thumb The second and even the third lumbrical may be supplied by either nerve, and this will determine whether the middle and ring fingers participate in the partial clawing deformity of an ulnar nerve lesion The first dorsal interosseous is not uncommonly supplied by the median nerve and clinical tests of ulnar nerve function based on the action of this muscle are unreliable

In cases of median nerve paralysis a further important consideration arises as to whether the ulnar nerve does or does not supply any portion of the thenar musculature which passes to the radial sesamoid of the thumb If it does, then

some degree of opposition of the thumb metacarpal is achieved by a combined action of these small muscles with the flexor pollicis longus, and the resulting disability is minimal If it does not *then the thumb metacarpal cannot be* brought away from the line of the fingers and rotated into any degree of opposition and a very considerable handicap results Very occasionally the ulnar *nerve supplies the whole of the thenar musculature, and a* median nerve injury at the wrist causes no demonstrable motor loss

Such variations make for some difficulties in the initial diagnosis of median and ulnar nerve injuries and in a proper assessment of their regeneration

The median nerve gives off its terminal branches under cover of the flexor retinaculum It is so well protected in the carpal tunnel that it is not often directly injured in this region although anything which increases the tension within this confined space may produce the compression changes referred to as "carpal tunnel syndrome." The nerve is usually damaged at or just above the wrist where it lies close to the surface, particularly in those people who do not possess a palmaris longus At this point it emerges from under cover of the flexor digitorum sublimis and lies to the radial side of the tendons of this muscle Here it is often confused with the tendons. Certainly it is much the same size as the tendons, but there the similarity ends Its colour is different it is dull *where the tendons are shiny and glistening, it has a small vessel running* on its ventral surface where the tendons have no such vessels and the "feel of the two structures is entirely different Moreover when tendons and nerves *are divided the nerve can be readily identified by the tassel of nerve fasciculi* which bulge from its cut ends Even if still in doubt it is a simple matter to determine that the proximal ends of the tendons emerge from muscle bellies and *the distal ends when pulled* on move appropriate finger joints.

Beyond the carpal tunnel (Fig. 13) the terminal branches of the median nerve fan out to their distribution accompanied by the common digital branches of the superficial palmar arterial arch The motor branch from the median nerve passes almost immediately into the short muscles of the thumb after leaving the tunnel and may be injured by a carelessly placed incision at this point At first the two digital branches to the thumb lie close together and for some distance are more on the flexor than the lateral surface of the thumb close by the tendon sheath of the flexor pollicis longus. Here all three structures lie in a groove which separates those of the short thumb muscles which pass to the radial sesamoid bone from those which pass to the ulnar sesamoid Beyond the metacarpo-phalangeal joint the nerves make their way farther round towards their respective sides of the thumb

The digital nerve to the radial side of the index finger is particularly susceptible to damage from superficial cuts on the radial side of the palm As it passes distally to gain the radial side of the index it lies subcutaneously on the fleshy belly of the first lumbrical where there is no well-developed aponeurosis to cover it At the base *of the finger this particular nerve* lies much more on the ventral surface and nearer the midline than do the other digital nerves This fact must be taken into account in designing incisions or raising flaps Cutting injuries in the region *of the second metacarpo-phalangeal* joint extending

from the flexor surface around the radial side of the hand frequently divide the flexor tendons, the radial digital nerve to the index, the first lumbrical and the tendon of the first dorsal interosseous.

The next two common digital branches of the median nerve as they pass to the webs between index and middle and between middle and ring fingers,



FIG 13
Arrangement of tendons and nerves in the palm.

lie much deeper in the palm in the spaces between the flexor tendons and protected by the palmar aponeurosis At their origin they lie in a plane superficial to the tendons but as they pass distally they are between the tendons and in the same plane The point of division of each of these into its two terminal digital branches varies considerably It is usually about the level of the distal palmar skin crease and well proximal to the point of division of the accompanying vessels.

MEDIAN NERVE AT THE WRIST

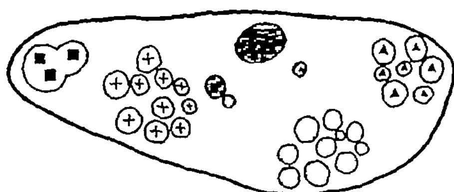
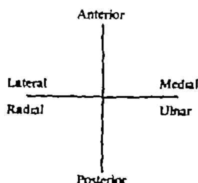


FIG 14
The orientation of fibres in the median nerve at the wrist
(*Sunderland.*)



Fibres for the thenar muscles.

Fibres for the second lumbrical

Cutaneous fibres from the third interspace

Cutaneous fibres from the second interspace.

Cutaneous fibres from the first interspace The fibres for the first lumbrical muscle are contained in this group

Cutaneous fibres from the radial side of the thumb

ULNAR NERVE AT THE WRIST

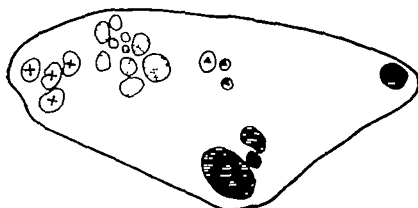
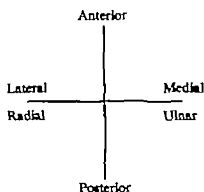


FIG. 14
The orientation of fibres in the ulnar nerve at the wrist.
(*Sunderland*)



 Deep division of the ulnar nerve.

 Cutaneous fibres from the hypothenar eminence.

 Cutaneous fibres from the ulnar side of the little finger

 Cutaneous fibres from the fourth interspace.

As the terminal branches of the ulnar nerve are more superficial and less protected near their origin they are more often divided in this region than are those of the median The main trunk of the nerve passes distally on the piso-hamate ligament, medial to the ulnar artery where it gives off its deep motor branch from its postero-medial surface Shortly after its origin this branch gives several small twigs to supply the short muscles of the hypothenar eminence and then passes deeply into the palm between the abductor digiti minimi and the flexor digiti minimi It then passes radially across the palm deep to the flexor tendons and usually supplies in turn the interossei the ulnar two lumbricals the adductor pollicis, and that portion of the flexor pollicis brevis which passes to the ulnar sesamoid of the thumb Injuries to the nerve occur not in the distal part of this course but close to its origin where it is not uncommonly damaged together with the other terminal branches of the ulnar nerve and the more medial of the flexor tendons This injury common in children often results from falls on the outstretched hand on to broken bottles or other sharp objects After giving off the deep motor branch the superficial portion of the nerve divides into two branches—a common digital nerve passing towards the cleft between ring and little fingers and a digital nerve to the ulnar side of the little finger The former crosses superficial to the flexor tendons *of the little finger and then runs a similar course to the common digital branches* of the median nerve. As the latter passes towards the ulnar side of the hand and little finger it crosses superficial to the abductor digiti minimi

Beyond the origin of the twigs to the lumbrical muscles the branches of the median and ulnar nerves are pure in type They can be readily sutured if divided without particular regard for meticulous orientation However when the main trunks of the nerves are divided at the wrist it is of great importance to their proper surgical repair that the ends should be accurately orientated and the surgeon must be aware of the position in the nerve of the motor fibres at these points (Fig. 14) In the median nerve at the wrist the motor fibres lie anteriorly and are often damaged in partial lesions. In the ulnar nerve the motor fibres lie postero-medially and can be separated out from the rest of the nerve for some distance This allows separate suture of sensory and motor portions when the point of section is close to the region where the nerve divides into its terminal branches

The surgical approach to the deep branch of the ulnar nerve can be difficult It is best achieved by raising a skin flap by an incision along the proximal palmar skin crease to the ulnar border of the hand then proximally to the wrist and laterally in the wrist crease (Fig. 15) The abductor and flexor digiti minimi can then be separated and the opponens detached from its origin to expose the distal segment of the nerve Care should be taken to preserve the small branches to these muscles which may arise proximal to the point where the nerve is severed This approach to the nerve is designed to give proper access for a difficult nerve suture. The approach described by Henry [1] does not achieve this object so readily Henry's incision may be an excellent one

[1] Henry A K. (1958). *Extensile Exposure applied to Limb Surgery* 2nd. ed. reprint, p. 116 Edinburgh E. & S Livingstone Ltd.

for drainage of the ulnar bursa, but his recommendation of its use for elective exploration and repair of a deeply placed nerve which may be injured in any part of its course is perhaps another example of the regulation of anatomical thought and surgical approach by considerations of sepsis

In the fingers the digital branches of median and ulnar nerves are prone to injury as they lie on the sides of the flexor sheaths in front of the accompanying digital vessels, and many cutting injuries where flexor tendons are divided also involve one or both of the digital nerves to that finger Close to the base of the finger each digital nerve gives off a small dorsal branch but the main nerve trunk remains as a substantial and sizeable entity right to the pulp of the finger



FIG 15
The incision used for exposure of the deep branch of the ulnar nerve.

THE TENDONS

THE FLEXOR TENDONS

In most expositions of surgical anatomy of the flexor tendons great stress is laid on the synovial sheaths their outlines and relations Rarely one finds reference in any detail to the anatomy of the tendons themselves and how they function We do not propose to consider the general plan of synovial sheath arrangement and the anatomical variations that occur but there are certain points concerning the synovial mechanism which are of importance from the functional standpoint in the surgery of repair In textbooks of descriptive anatomy a sharp line is usually drawn between the synovial tendon sheaths and the fibrous flexor sheaths in the finger as if these were completely divorced both descriptively and functionally From the point of view of reparative surgery however we are concerned more with what part of the tendon is surrounded by a loose filmy elastic medium and what part is surrounded by a denser and more rigid structure We are not interested in differentiating between the synovial sheath and the fibrous flexor sheath in the finger—for practical purposes they are one and indivisible For practical purposes, too the filmy elastic surrounding medium extends as far as the metacarpo-phalangeal joint and the rigid inelastic covering, the osseo-fibrous tunnel from the metacarpo-phalangeal joint to the tendon insertion. The significance of these facts is that proximal to the metacarpo-phalangeal joint a divided tendon can be repaired and can function despite some local scarring because of the elasticity of its surroundings. Distal to that point this is not feasible.

Another aspect of the tendon sheath system of some practical importance is the differentiation along the course of the digital theca of areas of greater and lesser thickening and rigidity The thickened areas constitute what has been termed the pulley system and are concentrated over the phalanges The

thinner areas are located over the interphalangeal joints to allow more freedom of movement at these points Whilst it is highly desirable to remove the greater portion of the digital theca to prevent rigid adhesions following on tendon repair it is equally important to preserve at least some portion or portions of the pulley mechanism to prevent anterior prolapse of the repaired tendon.

The other aspect of the tendon sheath system which merits attention is the mesentery of the tendon which has invaginated its synovial sheath It is through this mesentery as well as from its end attachments that the tendon gets its meagre blood supply In the finger the mesotendon is represented by the vincula (Fig. 16) The vincula brevia lie in the angles between the tendons and the bone at their insertion The vincula longa form an attachment between the posterior surface of the flexor tendons and the posterior wall of the tendon sheath which at this point is synovial lined phalangeal periosteum. It is the integrity or otherwise of the vincula which determines what happens to the proximal ends of the flexor tendons when they are divided in the finger When the point of division is beyond the attachment of the vincula and these latter structures remain intact the degree of retraction of the proximal ends is limited and they can usually be found not far from the point of section When the tendons are divided nearer the base of the finger and proximal to the attachments of the vincula, as commonly occurs, then the tendons retract deeply into the palm Though contraction as well as retraction occurs over the next few weeks they are always found beyond the distal edge of the transverse carpal ligament during the course of secondary exploration and repair Further retraction proximal to this point is prevented by the lumbrical muscles



FIG. 16
Post-mortem dissection of a finger to show the arrangement of the vincula.

The flexor tendons are in two groups—the superficial or flexor digitorum sublimis, and the deep which includes both the flexor digitorum profundus and the flexor pollicis longus

The flexor digitorum sublimis tendons at the wrist are in two layers those to the middle and ring being superficial to those passing to index and little fingers The tendons to index middle and ring fingers are all much the same in size, but that to the little finger is a very thin slip It can easily be overlooked by anyone who is unaware of its small size—a fact of considerable practical importance which has not been given due prominence Furthermore the sublimis tendons are quite discrete at the wrist and have no communication one with the other As they pass into the palm through the carpal tunnel they

diverge towards their respective fingers together with and superficial to the appropriate profundus tendons until they reach the digital theca. Soon after entering this tunnel the sublimis tendon divides into two elements which embrace the underlying profundus. These two diverging elements are reunited behind the profundus in the region of the proximal interphalangeal joint before continuing to their insertion along the lateral aspects of the flexor surface of the middle phalanx over a considerable part of its length These insertions of the sublimis tendon lie immediately inside the attachment of the digital theca Their nature is of considerable practical importance because cutting injuries involving the tendon are common at or just distal to the middle skin crease of the finger At this point it is common to find that the profundus tendon is completely divided and retracted towards the base of the finger while the two elements of the sublimis tendon are divided beyond the point of commencement of their linear insertion It is immaterial whether the proximal portion of the sublimis insertion which starts at the joint capsule of the first interphalangeal joint, is referred to as the vinculum breve or whether it is regarded as part of the true tendinous insertion—the effect is the same The result is that the sublimis tendon retains the proximal portion of its insertion and is still capable of a degree of function which largely depends on the amount of residual scar in the joint region.

The complete encirclement of the profundus tendon by the two elements of the sublimis is noteworthy, for the diameter of the tunnel so created is just such as will allow a normal profundus tendon to slide through It is obvious therefore that any repair of a profundus tendon at or just distal to this tunnel with its resulting reaction at the point of suture will mean that the repaired tendon jams in the tunnel and becomes adherent at this point It is sometimes necessary in certain operations of tendon transposition to detach the sublimis tendon from its insertion withdraw it in the palm and use it as a motor unit for some other purpose. It must be realised that this cannot be done successfully without a great deal of unnecessary trauma unless the point of cross union of the sublimis elements behind the profundus and the vinculum longum which anchors the tendon at this point are also divided before the withdrawal into the palm is attempted

The purpose of the flexor digitorum sublimis is clear in that its prime function is flexion of the proximal interphalangeal joints of the fingers. From the position of full finger extension through the normal range of flexion of all finger joints and with the wrist straight the excursion of the sublimis tendons or the proximal displacement of any fixed point of the tendon is 2 8 cm. in an average man While this is undoubtedly the normal and powerful action of the sublimis, its absence from injury or surgical removal produces little or no significant alteration in the function of the hand It has been stated[1] that normal finger flexion with both sublimis and profundus intact, starts at the proximal interphalangeal joint and then extends to involve the distal joint, whereas if the profundus alone is working the reverse occurs. Whilst this may

[1] Wood Jones (1942). *The Principles of Anatomy as seen in the Hand* London Baillière Tindall & Cox.

appear theoretically sound we have nevertheless frequently demonstrated that it is quite impossible clinically to make any such distinction if a patient is asked simultaneously and slowly to clench both his normal hand and a hand in which the flexor digitorum sublimis has been removed For this reason there seems little justification for repairing a divided sublimis tendon if the exposure and manipulation involved would in any way prejudice the functioning of a profundus tendon which is either undamaged or has to be the subject of surgical repair On the contrary it has proved sound practice to remove the sublimus tendon under such circumstances

The deep flexor system contains one muscle tendon unit, the flexor pollicis longus, which is usually completely detached another the flexor profundus to the index which has a variable degree of independence and three other elements, the profundus units to middle, ring and little fingers with still less independence At the wrist, unlike the flexor sublimis, the deep layer of tendons are all in the same plane Again unlike the sublimis except for the flexor pollicis longus the deep tendons are not at this point discrete entities but consist of a number of tendinous bundles with intercommunication from one to the other Pulling on any one of the bundles will thus activate more than one finger In the carpal tunnel this state of affairs persists and it is not until they emerge into the palm that discrete tendons to individual fingers are formed Whilst the flexor pollicis longus is usually independent it is however not uncommon to find some cross-attachment even between this tendon and the rest of the profundus group either in the forearm or in the carpal tunnel Some people are unable to flex the end joint of the thumb without simultaneously flexing the end joint of the index. The importance of this is apparent when the flexor pollicis longus is severed in the thumb and retracts to such a degree that the proximal end cannot be found easily through an incision on the thumb Under such circumstances the tendon must be isolated at the wrist withdrawn and then re threaded into the thumb This manœuvre is occasionally hampered by the type of cross-union described within the carpal tunnel and much damage can be done to the tendons if the reason for such hold up is not recognised

A further point of practical interest lies in the origin of the flexor pollicis longus tendon from its muscle belly This is a uni pennate muscle and the tendon arises over a long distance on the ulnar side of the muscle belly It is therefore a simple matter to detach the tendon origin from the muscle and to reinsert it at a lower level thus gaining up to one inch or more of additional tendon length This may be valuable in placing the point of repair of a divided flexor pollicis longus close to the insertion of the muscle instead of at the common point of section so obviating the effects of adhesion proximal to the interphalangeal joint

As they fan out in the palm towards the fingers the profundus tendons lie deep to the sublimis until they enter the digital theca where they pass through the tunnel formed by the sublimis over the proximal phalanx In this region they become superficial Their insertion is into the base of the distal phalanx beyond the capsule of the distal interphalangeal joint to which they are loosely

attached by the vincula brevia. The excursion of the profundus tendons in the movement of full flexion of the finger is 3·3 cm. in an average man

The precise origin of the lumbrical muscles from the profundus tendons is a further point of note. These little muscles four in number arise directly from the profundus tendons at the level of the distal edge of the transverse carpal ligament. The first arises from the radial side of the tendon to index, the second from the same side of the tendon to middle while the third and fourth arise from the adjacent sides of the tendons to middle and ring and ring and little fingers respectively As each muscle pushes its way out through the synovium surrounding the tendon it carries a prolongation of this sheath and passes distally on the radial side of its long flexor tendon deep to the neurovascular bundle. Its small tendon crosses the lateral aspect of the metacarpo-phalangeal joint to gain insertion into the radial side of the common extensor expansion to the particular finger These muscles, apart from their primary function of flexing the metacarpo-phalangeal joints also have some action in extending the interphalangeal joints They form an intimate connecting link between the flexor and extensor systems of the fingers The importance of this connection and its stabilising effect in relation to posture and the co-ordination of finger movements is something that cannot readily be analysed Nor is it of any great value to attempt to break up the intricate movements into their component parts, for in so doing we achieve only a rationalisation of a subdivision of movements which does not exist in reality It should also be noted that if the lumbricals remain intact when the profundus tendons are divided distal to their origin they limit the degree to which tendon retraction can occur Under such circumstances the proximal ends of the divided tendons will be found distal to the carpal tunnel even though years may have elapsed since the injury

THE EXTENSOR TENDONS

On the dorsum of the hand the extensor tendons are separated from the surface only by thin skin and a layer of loose areolar tissue At the wrist they are protected by the extensor retinaculum but distal to this they are frequently cut Such injuries occur particularly in the metacarpo-phalangeal and interphalangeal joint regions when the fist is clenched and the tendons tightly stretched over the back of these joints

The tendons are disposed across the dorsum of the wrist for the most part in a single layer despite their varied planes of origin in the forearm (Fig. 17) Beneath the extensor retinaculum they lie in a series of separate compartments The most radial of these lying over the styloid process of the lower end of the radius, contains the abductor pollicis longus and the extensor pollicis brevis The former is inserted into the base of the first metacarpal and the trapezium but tendinous fibres also frequently pass into the abductor pollicis brevis. Some degree of palmar abduction of the thumb can then be achieved by medium of these fibres in cases of median nerve paralysis The tendon of this muscle is sometimes in two portions, which may lead to confusion in identification

appear theoretically sound we have nevertheless frequently demonstrated that it is quite impossible clinically to make any such distinction if a patient is asked simultaneously and slowly to clench both his normal hand and a hand in which the flexor digitorum sublimis has been removed For this reason there seems little justification for repairing a divided sublimis tendon if the exposure and manipulation involved would in any way prejudice the functioning of a profundus tendon which is either undamaged or has to be the subject of surgical repair On the contrary it has proved sound practice to remove the sublimus tendon under such circumstances.

The deep flexor system contains one muscle tendon unit, the flexor pollicis longus, which is usually completely detached another the flexor profundus to the index which has a variable degree of independence and three other elements the profundus units to middle, ring and little fingers with still less independence At the wrist unlike the flexor sublimis, the deep layer of tendons are all in the same plane Again unlike the sublimis except for the flexor pollicis longus the deep tendons are not at this point discrete entities but consist of a number of tendinous bundles with intercommunication from one to the other Pulling on any one of the bundles will thus activate more than one finger In the carpal tunnel this state of affairs persists and it is not until they emerge into the palm that discrete tendons to individual fingers are formed Whilst the flexor pollicis longus is usually independent it is however, not uncommon to find some cross-attachment even between this tendon and the rest of the profundus group either in the forearm or in the carpal tunnel Some people are unable to flex the end joint of the thumb without simultaneously flexing the end joint of the index. The importance of this is apparent when the flexor pollicis longus is severed in the thumb and retracts to such a degree that the proximal end cannot be found easily through an incision on the thumb Under such circumstances the tendon must be isolated at the wrist withdrawn and then re threaded into the thumb This manœuvre is occasionally hampered by the type of cross-union described within the carpal tunnel and much damage can be done to the tendons if the reason for such hold up is not recognised

A further point of practical interest lies in the origin of the flexor pollicis longus tendon from its muscle belly This is a uni-pennate muscle, and the tendon arises over a long distance on the ulnar side of the muscle belly It is therefore a simple matter to detach the tendon origin from the muscle and to reinsert it at a lower level, thus gaining up to one inch or more of additional tendon length This may be valuable in placing the point of repair of a divided flexor pollicis longus close to the insertion of the muscle instead of at the common point of section, so obviating the effects of adhesion proximal to the interphalangeal joint.

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The extensor pollicis brevis is a thin tendon which runs alongside the abductor pollicis longus and then along the dorsum of the thumb to be inserted into the base of the proximal phalanx The extensor pollicis brevis is the only efficient extensor of the proximal phalanx of the thumb and if it is cut the extensor pollicis longus cannot reproduce this action effectively even with the assistance of the abductor pollicis longus to stabilise the metacarpal It is often cut together with the extensor pollicis longus over the dorsum of the metacarpal or together with the abductor pollicis longus at the wrist level, and in both situations it must be repaired as well as the larger tendon which it accompanies, or the resulting movement of thumb extension will be inadequate (Fig. 18)



Fig. 17
The arrangement of the extensor tendons on the dorsum of the hand

The second compartment is occupied by the tendons of extensor carpi radialis longus and brevis as they cross the wrist to the bases of the second and third metacarpals

The extensor pollicis longus occupies the third compartment on the ulnar side of Lister s tubercle It then turns sharply radially across the wrist extensors to its insertion into the base of the terminal phalanx of the thumb This tendon is commonly injured over the back of the metacarpo-phalangeal joint together with the tendon of the extensor pollicis brevis as mentioned above The extensor pollicis longus when cut at or proximal to this region may soon retract well up into the forearm It is easily repaired primarily but secondary direct repair may be impossible even if attempted within a few weeks of injury

The fourth compartment at the wrist is occupied by the extensor digitorum communis overlying the extensor indicis proprius In this region the extensor communis is not yet completely separated into its component tendons. The extensor digiti minimi occupies the fifth compartment over the dorsal surface of the inferior radio-ulnar joint and the final compartment is for the extensor carpi ulnaris in the groove between the head and the styloid process of the ulna

On the dorsum of the hand all tendons passing to the fingers come to lie in the same plane, so that the extensor indicis proprius lies along the ulnar side of the common extensor tendon to the index and the extensor digiti minimi has a similar relation to the common extensor tendon to the little finger

The two extensor tendons to index are independent structures as far as the metacarpo-phalangeal joint Beyond this they have a common attachment

and are indistinguishable in the extensor expansion over the dorsum of the finger The extensor tendons to the ulnar three fingers however are united proximal to the metacarpo-phalangeal joints by lateral expansions known as the vincula accessoria Occasionally such a band also joins the common extensors of middle and index but it is never as well defined The arrangement of the extensor tendons to the ulnar three fingers is somewhat variable Sometimes there is no common extensor tendon to the little finger this being represented simply by one of the vincula passing from the common extensor to the ring finger across to the extensor digiti minimi. The common extensor to the ring finger may be single or split into two or three portions The degree and situation of its communication with the tendons to middle and little fingers are variable

Whatever their arrangement on the hand the tendons to each finger are fused into a broad expansion over the knuckles Here the expansion gives off from each side at right angles a broad sheet of fibres which passes around the side of the metacarpo-phalangeal joint to blend with the joint capsule These broad sheets, sometimes referred to as hoods cover over and conceal the important collateral ligaments of the joints From the deep surface of the expansion just beyond the joint some fibres pass to an insertion at the base of the proximal phalanx. Beyond this the extensor expansion becomes thinner and flatter and separated from the phalangeal periosteum by only a thin layer of loose areolar tissue Under certain circumstances of prolonged immobilisation sepsis or œdema this loose gliding plane is replaced by a plane of fixed adhesion between tendon and bone This accounts for much of the disturbance of posture and function associated with such conditions Over the proximal phalanx the expansion is split into three portions The central slip is inserted into the base of the middle phalanx whilst the two lateral slips, joined in turn by the tendons of the interossei and the lumbricals, pass on over the middle phalanx where they reunite before being inserted into the base of the distal phalanx



FIG. 18

The effect of loss of action of the extensor pollicis brevis tendon

Both extensor pollicis longus and extensor pollicis brevis have been cut, but only the continuity of extensor pollicis longus has been repaired. There is inability to extend the thumb in the abduction position.

The Actions of the Extensor Tendons—The abductor pollicis longus abducts the thumb metacarpal in the same plane as the hand. It also has a powerful

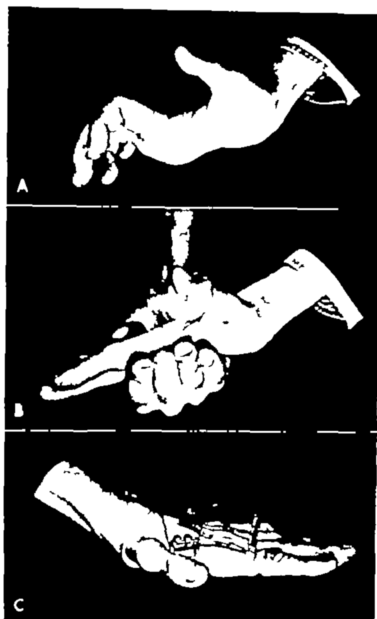


Fig 19

A case of poliomyelitis of many years standing with complete loss of function of all the small muscles of the hand

A, Strong attempt to straighten the fingers produces only hyper extension of the metacarpo-phalangeal joints.

B As soon as the metacarpo-phalangeal joints are controlled the fingers can be straightened at the interphalangeal joints.

C, The use of a simple splint to control the degree of metacarpo-phalangeal joint extension.

action in abducting the wrist In cases of median nerve paralysis it is an important element in the trick movements which may simulate true opposition

This is because of its frequent attachment to the abductor pollicis brevis and its ability to combine with the adductor pollicis in displacing the thumb metacarpal towards the palm

The extensor pollicis longus not only extends the end joint of the thumb and to a lesser extent the metacarpo-phalangeal joint, but it also brings the whole thumb dorsally and towards the ulnar side so that it lies close to and in the same plane as the index This position not of abduction but of adduction is of some importance in immobilising the thumb following injuries to this tendon.

The actions of the long extensor tendons to the fingers are complex Their prime function is extension of the metacarpo phalangeal joints Extension of the interphalangeal joints is primarily a function of the intrinsic muscles through their insertion into the lateral slips of the extensor expansion The long extensors, however, are capable of limited action in extending the interphalangeal joints provided the metacarpo-phalangeal joints are stabilised in some degree of flexion Without such stabilisation even the most powerful contraction of the long extensors will succeed only in hyperextending the metacarpo-phalangeal joints and have little or no effect on the interphalangeal joints (Fig 19 A B and C) This can readily be demonstrated in cases of combined median and ulnar nerve section at the wrist If a splint is devised for these cases, which will prevent hyperextension of the metacarpo-phalangeal joints then the interphalangeal joints can be extended by the long extensor tendons.



FIG 20

The effect of division of the extensor expansion in the knuckle region on finger extension

A, The characteristic movement which follows an attempt to lift the middle finger tip off the table.

B, The normal movement in the opposite hand.

Because of the vincula accessoria, section of one or more of the tendons proximal to the metacarpo-phalangeal joints may not be clearly demonstrable clinically Beyond the vincula cuts in the knuckle region result in an exaggerated flexion posture at the metacarpo-phalangeal joint. Any attempt to extend the finger results only in a characteristic effect of increased flexion at the metacarpo-phalangeal joint and straightening of both distal joints by the action of the intrinsic muscles (Fig. 20 A and B)

It is sometimes stated[1] that when the metacarpo-phalangeal joint is fully

[1] Couch. *Surgery of the Hand* Toronto University Press.

extended extension of the interphalangeal joints of the finger can only be achieved by the long extensor tendon the lumbrical and interosseous system only producing extension of these joints in a flexed position of the metacarpo phalangeal joint This thesis is not substantiated in practice and any clinical tests based on this assumption must be erroneous Either system can extend the interphalangeal joints no matter what the posture of the metacarpo-phalangeal joint but only if the other system is intact. Each requires the integrity of the other to fix the metacarpo-phalangeal joint so that its action is not lost on moving this joint. Thus it is that in an ulnar nerve paralysis there is hyperextension of the metacarpo-phalangeal joint and loss of extension in the interphalangeal joints when the small muscles are paralysed.

The necessary composite action of the two systems is also demonstrated by the curious and typical movement produced by attempts at extension of the metacarpo-phalangeal joint when the long extensor tendon is cut, as already described

Most mistakes of interpretation arise by trying to separate the functions of the long extensor and small muscle mechanisms when indeed, they are complementary and inseparable

In addition to these actions in extending the fingers the long extensor tendons are capable of some degree of abduction at the metacarpo-phalangeal joints producing a fanning out of the fingers This action which is opposed by the action of the long flexor tendons which tend to adduct as well as flex, may produce trick movements simulating the actions of the interossei when these are paralysed in ulnar nerve lesions.

The extensor tendons, unlike those on the flexor surface are flat and not rounded They have differentiated synovial sheath arrangements in relation to their passage across the wrist under the extensor retinaculum. Beyond this they are surrounded only by a loose filmy paratenon Their proximity to the surface and to the underlying bone or joint exposes them not only to injury from without but also to damage and subsequent adhesion in the case of fractures of the metacarpals and phalanges The excursion however is short and adhesions therefore of less importance than in the case of flexor tendons.

THE JOINTS

The successful restoration of function to an injured hand depends more upon the free active range of the metacarpo-phalangeal joints than on any other factor Apart from the usual circumferential capsular arrangement each metacarpo-phalangeal joint has two well-differentiated collateral ligaments (Fig. 21) These pass from a small pit well back on the side of the metacarpal head distally and obliquely forwards to the side of the proximal phalanx This direction means that the ligaments are tight in flexion and slack in extension. It can be readily demonstrated that lateral movement of the joints is much freer when the fingers are extended than when flexed due mainly to the varying tension of the collateral ligaments If the metacarpo-phalangeal joints are immobilised in extension for any period these ligaments contract

so that even in extension abduction and adduction of the fingers is limited and flexion of the joints is no longer possible This state of affairs is commonly

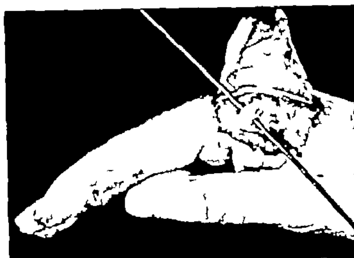


FIG 21

The lateral ligament of the metacarpo-phalangeal joint is a definite and substantial structure. Here it has been exposed through a window dissection on the radial side of the index finger and the probe passed beneath it.

seen in relation to burns of the hand and other injuries where immobilisation in extension has been allowed to continue for too long. Another factor responsible for the efficiency of the mechanism for stabilising the metacarpo-phalangeal joints when the fingers are flexed in a position for fine finger tip control is the shape of the articular facet on the metacarpal head As this is wider anteriorly than posteriorly the joint surfaces fit closer together in the flexed position than in the extended position (Fig 22)



FIG 22

An open metacarpal joint viewed end on The head of the metacarpal is broader anteriorly so that the fit of the joint becomes firmer in flexion.

The interphalangeal joints have a similar capsular arrangement but the opposing bony surfaces are such that lateral movements are very limited Prolonged immobilisation in extension leads to limitation of flexion more because of extensor tendon fixation than because of ligamentous contraction Long-continued flexion posture, as in the case of small muscle paralysis or conditions such as Dupuytren s contracture leads to anterior capsular contraction This is generally permanent even though all other factors concerned in the deformity are relieved

CHAPTER III

ORGANISATION IN RELATION TO HAND INJURIES

GENERAL CONSIDERATIONS OF ORGANISATION

THE *necessity for sound organisation must be regarded as a principle of* modern surgery. Surgeons *can no longer stand aloof to administrative* arrangements or political trends which induce compromise in the proper organisation of their work. It is easy to remain shut off from such matters *under the delusion that our only concern is* with the professional care of the sick and injured. To accept compromise *in organisation is tantamount to* accepting compromise in standards of treatment, for the proper care of patients to-day requires administrative arrangements based on surgical principles. *Surgeons who alone can appreciate the importance of these principles must* insist upon their observance.

Under the conditions that commonly prevail all surgeons have frequently to make concessions because of shortcomings of organisation—a daily reminder *of how far present hospital organisation is* short of technical advances in surgery. Life long campaign against the necessity for such compromise is therefore a responsibility of surgeons.

We say this not in any unrealistic attempt to gain for a particular branch of surgery a *place in the sun but rather to place hand surgery in its right* perspective. It is fully realised that the competing demands of all facets of practice must be correlated. That, however, is an administrative matter in which local practical considerations might outweigh surgical principles. We repeat, *however, that it is only by keeping organisation abreast of surgical* progress that its advantages accrue to the mass of patients.

The age of individualism covering the whole field of surgery is succeeded by the era of close team work with its many advantages. Integration of knowledge and effort by thorough *organisation is an antidote to the criticism,* oft vented, that surgery is becoming over fragmented and surgeons over-specialised. There are obvious dangers in the over-development of specialist treatment inherent in the very nature of medical practice, *but it must be accepted that most modern developments of surgery* are due to widespread recognition of the fact that individual surgeons can no longer hope to be equally proficient in all branches of surgery. Whilst, however, the development of separate branches in relation *to the common stem of medical practice* is generally accepted and the advantages recognised, it is not so widely understood that ancillary services and hospital facilities must simultaneously develop similar offshoots. Most special developments of practice require a skilled team *working* under conditions primarily *adapted to the particular nature* of the work and not to some common trend of hospital organisation. This implies case segregation which in turn is a principle of modern surgical organisation.

Where hand injuries are concerned, such are *the humanitarian* and *economic issues at stake to patients* that the personal and party considerations

which involve interrupted management by inexperienced surgeons must be subservient to the rights of the injured to receive the continuous and integrated service of modern surgery and facilities.

Two principles must be satisfied in proper organisations for the management of hand injuries.

1. The Overwhelming Importance of Primary Treatment

To-day the result achieved after any hand injury depends for the most part on the efficacy of primary treatment. Standards of wound closure must be of the highest order if the full benefits of modern primary reparative procedures are to be obtained. Secondary repair can never make good the time or opportunity lost by neglect of proper primary procedures. The results and economy of primary repair far exceed those of secondary procedures when carried out after sepsis and long immobilisation have caused scar tissue and loss of function. There is the difference of a world in the prognosis of a compound wound which is truly converted to a closed injury at primary operation and one in which this desirable object is not achieved.

The main responsibility of management of a hand injury lies with the surgeon who conducts the primary treatment. With so much at stake it is axiomatic that this treatment should be carried out by surgeons equal to and conscious of their responsibility and under conditions befitting any ramifications of operative procedure which might be indicated.

In the past it has unfortunately become widespread and ingrained habit in hospital practice for the care of hand injuries to fall to the lot of junior men in casualty appointments; while each may have little understanding of the true significance of what he regards so often as a surgical chore. Standards of treating hand injuries cannot be uplifted or maintained by such arrangements. Minor surgery has been well defined as surgery by minor surgeons. Whatever may be the meaning or range of so-called "minor surgery," hand injuries do not fall within its scope.

2. Continuity of Management and Responsibility

Each case must be a single surgeon's continued responsibility. He may see fit to delegate some cases or details of management to others under his direct control and supervision. This is very different from a common state of affairs where the senior and responsible man sees only those cases which are complicated or those at a delayed phase of their management. If he has never set eyes on the case before he can have no reliable conception of what was indicated, what was done or how it was done. If a junior man is competent to undertake primary treatment it is fair argument that he should be competent to treat the case all through. He will certainly learn nothing of the case if it is caught in the machinery of an institution and ceases to be his own personal pride and responsibility.

It is obvious that students and housemen must be trained, but we must see that they are trained by apprenticeship methods and not at the expense of the patient's interests. The direct supervision of senior and responsible surgeons

is necessary at all stages and for all cases If work is well done in an institutio students will be well taught by precept and example

Certain traditions of hospital administration rather than of ideal surgi practice frequently hinder the efficient management of hand injuries. C of these lies in a rigid division of in patient and out patient classification this system certain facilities of theatre and personnel are available to a pati only if he is admitted to a hospital bed. Otherwise his surgical care, no l important must be carried out under incomparably inferior conditions in busy casualty or out patient theatre where hand injuries form only part the well known mêlée of petty sepsis and the hundred and one other emergen problems of a busy hospital Not until every hand injury is admitted to t care of some responsible surgeon under common basic conditions will t handicap be relieved. After primary treatment is completed the patient m or may not be retained in hospital. That should be the surgeon s decision, be made after and not before treatment is undertaken

The reorganisation of facilities and of teaching in the casualty departm of Guy s Hospital London, shows a recognition of the necessity for adaptati to the modern needs of proper finite treatment of all hand injuries.[1, 2] This a highly significant trend in a famous teaching hospital.

Under existing conditions it is generally difficult to get a patient admitt to hospital but once admitted it is often more difficult for him to be discharg that same day or perhaps even the next day This is a matter of administrati which surgeons could well break down Furthermore, under prevalc conditions it is left for a junior man to decide which cases should be admitt to the care of a senior man and which he will undertake himself In an id set up it is the reverse which would apply

Primary treatment of hand injuries should be undertaken only where the are proper operating theatre facilities Any shunting of cases or unnecessa handling which delays access to such facilities is wasteful both of effort a precious time for the timely application of primary treatment ranks next importance to the standards of that treatment. Within reasonable limi however time itself can be no ready excuse nowadays for the conduct primary treatment under unsatisfactory makeshift conditions. The gene drift of this work to hospital practice is therefore inevitable because it is rigl

First aid care, casualty management and definitive hospital treatme must all be adapted to these principles

FIRST-AID INSTRUCTIONS

Employers to-day realise the importance of proper first aid and medic care of their workers so that any factory of size has special facilities and train personnel for first aid. The St John s Ambulance teaching has rendered notable service in this field and will continue to do so

[1] Clarkson, Patrick (1951). The training of dressers in tissue craft. *Lancet* 1 1242.
[2] Clarkson, Patrick (1948). Out-patient arrangements and accident services *Guy s Hosp G* 31st July

Every hand injury should be reported and every minor skin cut or abrasion properly cleaned covered and kept covered It should be the supervisor foreman or first aid attendant, and not the worker himself who should decide which injuries require medical attention It is significant that most of the infective complications of hand injuries arise by infection of minor and neglected lesions not from the gross injury which is treated in hospital Sumner Koch [1] of Chicago where vast numbers of hand injuries occur attributes the rarity of infected hand wounds not so much to antibiotics as to the universal acceptance and practice in that city of the proper care of minor injuries among workers It would seem to the casual observer in street cars and on sidewalks that nearly every second person wears a dressing on a finger

First aid care of major injuries should follow an orderly sequence in an atmosphere of calm directed to the control of hæmorrhage by pressure dressing or tourniquet if severe to general anti-shock measures and reassurance to the effective cover of the injured area and to adequate splinting of the part Where any choice is permitted the use of cotton wool as a direct first aid application to raw areas should be avoided. It takes much time and patience to clear a recent wound of shreds of blood sodden wool, and attention has more recently been drawn to the order of the foreign body reaction and fibrosis which occurs about shreds of cotton wool which are inadvertently left in healing wounds

CASUALTY RECEPTION AND MANAGEMENT

It is of main concern here that there should be a minimum of repetition of what has already been done, provided it has been done effectively A tourniquet may require removal or readjustment—usually the former There are but a few cases of bleeding from wounds of the hand which cannot be well controlled by an ample pressure pad of gauze firm overall bandaging immobilisation and elevation. Only on occasions at this stage, do we need to use hæmostatic forceps to control specific bleeding points It is unfortunate that important nerves lie in close proximity to the very vessels where hæmostats are sometimes indicated *e g* the ulnar artery median accompanying artery (sometimes large) deep palmar arch or occasionally a small digital vessel Great care is therefore required in the application of forceps New house surgeons are frequently over-enthusiastic about such activities Panic and indiscriminate grabbing at bleeding among areas of blood clot without a clear vision of the specific point can cause much harm.

Immobilisation of the region is a particular requirement for a patient s comfort. Hands with mangled remnants should not be left flopping round without a well applied splint for wrist control The man with his injured hand well bound up on an effective splint presents quite a different general picture to the unfortunate who is being moved from pillar to post between casualty X ray ward or operating room, endeavouring to support his own forearm with a few Spencer Wells forceps dangling from an oozing wound loosely covered by a gory so-called sterile towel"

[1] Koch, Sumner L. Personal communication.

The indications of pain should be met. Shock should be noted and treated if present. The possibilities of other injuries especially considered in relation to cause of injury must be properly excluded by routine examination. Every endeavour should be made by casualty organisation to prevent unnecessary interference Multiple examinations by casualty doctor registrar house surgeon and surgeon are to be deprecated

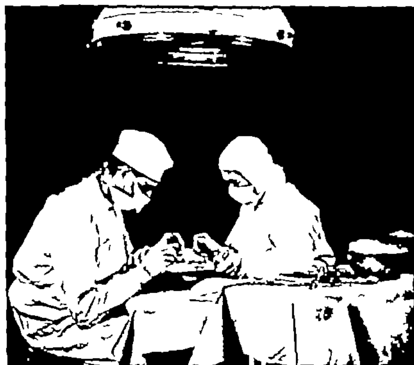


FIG. 23

Theatre arrangements for hand operations must be conducive to precision surgery Order freedom of movement, good lighting and an atmosphere of relaxation provide these conditions.

OPERATING THEATRE ARRANGEMENTS

Theatre arrangements for hand surgery do not require to be elaborate (Fig. 23) but must be precise and orderly so that an atmosphere of equanimity is provided for meticulous work An excess of the normal requirements of personnel and equipment for hand operations becomes an impediment to quiet and efficient procedure, the necessary background for good work to surgeons even of ordinary temperament It is the patient who suffers from theatre disorder and fuss

Details of theatre arrangement can never be divorced from personal considerations A surgeon an assistant a theatre nurse and an anæsthetist constitute the normally required team Personnel above these numbers embarrass freedom of movement and lend only a claustrophobic effect to any long tedium of hand repair

A qualified assistant is indispensable to most hand operations Much time is saved for the patient s benefit by one who knows the surgeon, has a working knowledge of technique used and who can appreciate the importance of certain manipulations or of a posture which he might be asked to hold for long periods Good assistance makes for the smooth conduct of an operation whilst the reverse is soon manifest in general irritation

The requirements of the preparation should be separately available at the commencement of the operation A *splash bowl with a liberal*

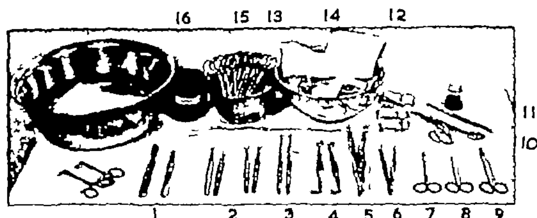


Fig 24

The fine instruments required for hand repair

These are *few* but essential

1 Bard Parker blades, Nos. 22 and 15
2. *Fine double skin hooks.*
3 Single skin hooks (Gillies)
4. Catspaw retractors.
5 Fine non-toothed forceps (Macindoe)
6. Fine toothed forceps (Gillies).
7 Curved eye scissors.
8. *Straight eye scissors.*
9 Dressing scissors.
10. *Gillies needle holder*
11 Pen and ink.
12. Threaded sutures (silk).
13 Bunnell's probe and tendon threader
14 Gauze and dressings.
15 Mosquito hemostats.
16. Light Esmarch s bandage.

supply of warm water and soap a few packs and swabs a bucket and a one-gallon jug of normal saline are all that is generally required for this purpose

All linen, instruments and suture materials should be available from a single trolley under the care of the theatre nurse who should take no part in the preparation of the hand

The instruments needed for hand repair are essentially those in routine use by the plastic surgeon (Fig. 24) with certain additions pertinent to the requirements of particular cases of tendon repair skin grafting or special procedure The necessary techniques of accurate suturing, atraumatic handling of tissues or finesse in the repair of hand structures cannot be achieved without correct instruments and suture materials

We have found a hand-stand of the type illustrated in Fig 25 most useful, and it should be included in the layout for all operations on the palmar aspect

of the hand, especially those involving tendon repair A convenient and fixed posture can be maintained for long periods without the embarrassment of extra hands in an already restricted field where precise control and every possible freedom are required for accurate work



FIG. 25

The author's hand-stand

This provides excellent working conditions for many hand operations.

In conformity with the principle of continuity of management every surgeon who performs the initial repair of a hand should regard himself responsible for its total management Details of after-care are his personal responsibility and the controlling organisation should be elastic enough to permit of this Any physiotherapy should be under his direction and supervision So too should rehabilitation which is an integral part of total management.

CHAPTER IV

THE EXAMINATION AND APPRAISAL OF A RECENTLY INJURED HAND

ASSESSMENT of the damage to an injured hand is the personal responsibility of the operating surgeon The more impersonal this essential function becomes or the more it is delegated to others the less satisfactory end results will be Results can be spoiled by malcontented patients if divided management ignores their personal considerations Furthermore, anyone who bases his operation on the unchecked observation of another surgeon will often be forced to unconsidered decisions, to the patient's detriment and his own dissatisfaction His findings at operation may prove contrary to information and may indicate some method of treatment perhaps even amputation which has not been discussed with the patient

Elaboration of the optimum plan of management for any patient involves two strong personal factors It serves little practical value to recite to him what can be done or has been done by other surgeons when it is the capability and experience of his own surgeon which is paramount This in turn must be adapted to the patient himself it must respect his wishes and be ratified by him in the mutual understanding of the doctor patient relationship in its fullest sense.

The full appraisal of a patient with a hand injury is ultimately achieved by the following considerations.

THE NATURE AND CIRCUMSTANCES OF THE INJURY

Two hours ago—patient caught hand in a machine at work. Such is a typical bare and blunt statement so commonly found on history sheets The mere statement of hours which have elapsed since injury to-day means little without some clear understanding of the exact nature and circumstances of the injury and precise information on what has been done to the hand since the injury occurred The elucidation of how a particular injury was produced and why it happened may be useful in diverse ways What was the position of the hand or its state of function when the injury occurred? Have the tissues been subjected to gross compression types of injury? What factors have been involved which would predispose to early establishment of infection? Such may be found in the nature of the injury itself the state of the skin or the degree to which meddlesome first aid or casualty interference has been practised whether in exploration for foreign body in search for cut and retracted tendon ends, or perhaps in the enthusiastic abuse of antiseptics. All these are factors which have particular application in certain types of injury

A further reason for detailed accounts of injury is that surgeons have some responsibility in accumulating information which would facilitate accident prevention.

THE VIEWPOINT OF THE PATIENT

There are no rules of thumb for mass management of hand injuries There are many factors which reduce details of management to individual considerations of a patient. Such are his age, his mentality whether he is right or left handed or whether he has been injured before We should *ascertain to what limits the function potential of his hand is extended at his* work or his leisure—for the problems of a musician are entirely different to those of an unskilled labourer Much depends also on the total severity of the injury for the more mutilated the hand the more important conservative procedures for its remnants become A procedure unwarranted on a finger of a hand otherwise intact may be of prime importance on a hand with only two or three fingers present and possibly the other hand also injured

Furthermore, it is important to sense what is the patient s reaction and attitude to his injury In most cases it causes no hardship to hear with patience a man s own account of his injury This is most helpful in encouraging an outlook conducive to the best result in the shortest time. The man who is resentful of his injury and eager to lay blame on others or the man who is self persecuting and ashamed of his injury exemplify extreme attitudes which require psychological help and adjustment for a healthy recovery Such demands can more easily be met if the surgeon has early knowledge of them

THE CLINICAL EXAMINATION OF THE INJURED HAND

GENERAL FACTORS AND LIMITATIONS

There are two complementary fractions to the examination of any hand recently injured beyond a trivial degree—the essential examination preliminary to operation and a further detailed examination which is better carried out *on the anæsthetised subject or region The pre-anæsthetic* examination essentially concerns the whole hand and its function whilst the examination under anæsthesia is concerned with details of the wound itself

Outside an operating theatre examination of the wound should be limited to the determination of what region is involved and what structures are suspect so that the continuity or functional activity of these structures can be established or otherwise by the more simple clinical tests Any detailed examination of the wound itself should be withheld at this stage These details will be included as an essential stage of operative procedures in the next chapter

The general examination of an injured hand is an easy exercise of applied anatomy After study of the region and nature of injury it should proceed in definite order of all the anatomical structures which might be damaged Mistakes can only arise by errors of omission at examination or by ignorance of the specific function of structures and the methods by which these can or cannot be clinically demonstrated

In making any systematic examination of function of an injured hand we must be aware of the following two opposing generalities —

1 *A particular movement is often much diminished or even absent when the structure primarily responsible for that movement is intact* The common reason for this is obvious Because of pain at the site of recent injury the patient wittingly or unwittingly limits the movement of neighbouring structures. This is unavoidable, but it is frequently complicated by an avoidable factor if the patient is not absolutely clear of what he is expected to do This is best overcome by demonstration rather than by explanation The surgeon should demonstrate with his own hand what he is asking the patient to do, and the patient in turn should confirm this by demonstrating and, if necessary, practising the movement with his normal hand For example many patients when asked to bend a finger without proper demonstration will proceed with a rapid multiplicity of alternating and incomplete flexions and extensions of all fingers This is confusing, difficult to follow and often misinterpreted It contrasts with the desired effect of one attempt at a single complete and unassociated movement If this is first demonstrated by the patient with his normal hand not only do we know that he is clear about the test but we have a useful opportunity of comparison with what he can normally accomplish as independent movement. The capacity for independent flexion or extension of fingers is subject to wide individual variations.

In children in particular the effect of pain may completely prevent the demonstration of a specific movement.

Another cause of diminished or absent movement is sometimes found in the effect of hæmatoma accumulation in the region of injury especially if blood collects and tracks along tendon sheaths

Joint injuries or intra articular fractures may also inhibit movement with intact tendons

In the case of certain nerve injuries it is well known how function may be impaired or absent for a varying time without anatomical discontinuity of nerve structure

2. *A particular movement may be present in varying degree when the structure normally responsible for that movement is not intact* This especially applies in relation to tendons injured in certain situations Each muscle tendon and nerve in the hand has a clinically demonstrable function. Such function however is not always specific to a particular structure, and is only clearly defined by clinical tests in cases of injury at some point beyond which that structure becomes anatomically independent. With a wound on a finger for example, if the patient cannot flex the distal interphalangeal joint of this finger when the middle phalanx is held by the examiner the flexor digitorum profundus tendon has been divided In the case of a wound at the wrist, however the same tendon may be divided and yet the distal interphalangeal joint is often capable of some independent flexion This is because of intercommunication which may exist between neighbouring profundus tendons distal to the point of section. Admittedly this spurious function may be only a weak and partial

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THE CLINICAL EXAMINATION OF THE INJURED HAND

General Factors and Limitations

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flexion but no weaker than is often noted with an intact tendon when there is a painful wound in its neighbourhood

Continuity of synovial sheaths or attachments may also have bearing on the reliability of clinical signs when tendons are sectioned This is especially noted with those tendons which have common association with the ulnar bursa, for if one of these is intact it can produce movement through the continuity of the bursa and the distal segments of other tendons which are severed within the region of the bursa When all tendons to middle, ring and little fingers are cut at the wrist it can be easily demonstrated how traction on the distal segment of a little finger tendon for example may produce flexion of all three fingers. We have often noted the same effect produced by active movement when one of these tendons is intact and the others severed A similar phenomenon is often demonstrated on the back of the hand in the case of the extensor tendons because of connections by the *vincula accessoria*

Thus there are many fallacies to detailed clinical tests of injured hands, and it must be accepted as a working principle therefore, that **any wound of the hand is presumptive evidence that all deeper structures in the region are severed until their anatomical continuity is confirmed by clinical examination with due regard for its fallacies, or by operation** This has particular application in relation to nerves and tendons, when the surgical indications for operative exploration are frequently analogous to those of penetrating wounds of the abdomen

Only if the above implications are realised can true value be obtained from the ordered examination of hand function which can proceed as follows —

Tests of Tendon Function

1 **The Studied Posture of Hand and Fingers** —Apart from the obvious deformations of fractures and dislocations much can be learnt from a study of the posture of an injured hand The hand is generally held by the patient in the relaxed position already discussed This can easily be demonstrated on the patient s sound side If any of the long tendons are severed the balance of tendon tension which is responsible for the posture of a finger is upset and the affected finger then lies out of its normal relative alignment. If a flexor tendon is cut (Figs 26 27 and 28) the finger lies extended from its normal position while if the extensor tendon is cut it is more flexed than it should be (Chapter VII Fig. 76) Furthermore, the abnormal lie of the injured finger is made more obvious by passive extension or flexion of the wrist as the case may be This is a most reliable objective sign of severed flexor tendons and it is often the only reliable sign in children Much more value should be attached to this simple observation of finger posture than is generally attached to the results of diverse attempts at active movement

2 **The Tendon Tension in the Fingers** —If an examining finger tip is placed on the pulp of each finger in turn and pressed lightly the flexor tendon tension can be gauged With a little experience in this test it is the best objective test of divided flexor tendons If roughly carried out this test is painful

3 **Tests of Tendon Continuity by Movement** —For reasons already given only in particular situations can real value be placed on the absolute diagnosis of tendon injuries by subjective clinical tests which involve active movement These are as follows —

In the case of flexor tendons (*a*) In suspected injuries of the flexor pollicis longus tendon in the thumb, if the patient cannot flex the interphalangeal joint



FIG 26

The effect of tendon injury on finger posture

In this case it is obvious that the flexor tendons of the index finger have been cut because of the finger which lies extended out of its normal postural relationship with the other fingers. Moreover the abnormal posture of the index finger does not change with (A) flexion or (B) extension of the wrist.

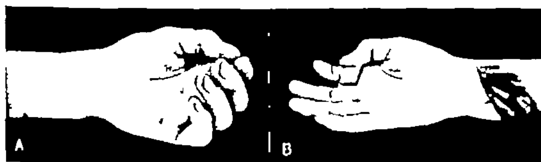




FIG 27

Tendon injury and finger posture

A Posture of normal hand.

B, Posture of injured hand. It is obvious that middle, ring, and little finger tendons are cut while the thumb and index finger tendons are intact.

C, After repair of the tendons—normal posture is restored.

of his thumb when the proximal phalanx is held by the examiner the flexor pollicis longus tendon is severed (*b*) With a wound on the finger if the patient has no independent flexion of the distal interphalangeal joint beyond the normal recoil from hypertension, the flexor digitorum profundus tendon to that finger is severed (*c*) With a wound on the proximal end of a finger or in the palm of the hand if the patient has no independent interphalangeal movement in

either joint when the metacarpo-phalangeal joint is fixed by the examiner then both flexor tendons are severed

In the case of extensor tendons these too can only be diagnosed beyond a stage of presumption when cut in particular situations (*a*) With a wound in the region of the metacarpo-phalangeal joint *i.e.*, between the vincula accessoria and the lateral contributions to the extensor expansion if the patient

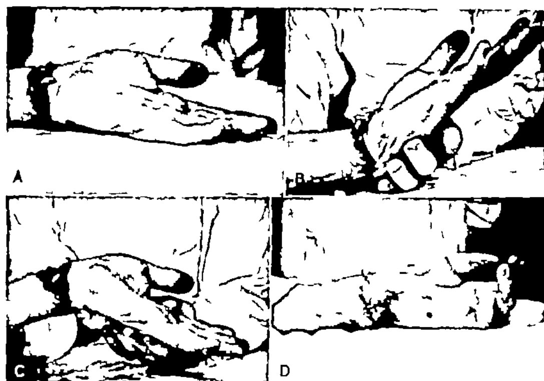


FIG. 28

Posture changes with extensive flexor tendon injury at the wrist

A, The universal absence of normal posture in all fingers and thumb is apparent.
B C This is not varied by passive flexion or extension of the wrist
D Immediate restoration of normal posture after suture of all flexor tendons.

cannot hyperextend the metacarpo-phalangeal joint with the interphalangeal joints flexed as in the movement which precedes striking a piano note the long extensor tendon or tendons to the particular finger must be severed His attempts to do this movement when the long extensor tendon is cut cause a characteristic straightening of the finger and *flexion* of the metacarpo-phalangeal joint (Fig. 20) (*b*) With a wound in the region of the distal interphalangeal joint the mallet finger deformity is immediately observed though at this stage it is not gross and the patient cannot actively extend the flexed distal interphalangeal joint. (*c*) Injury to the extensor pollicis longus tendon at any point in its very independent course can be diagnosed by the loss of independent extension of the interphalangeal joint of the thumb when the metacarpo-phalangeal joint is controlled by the examiner

In all these active movement tests it should be noted that (*a*) they are all subjective tests of little or no value in young children (*b*) in testing movement

of a particular joint the proximal joint must be controlled by the examiner (c) an impaired range of movement is not of absolute diagnostic significance Positive diagnosis of severed tendons can only be assessed on complete absence of movement.

In all situations other than those indicated, and especially on the flexor aspect of the wrist it is the position of the wound itself which must be taken as presumptive evidence of tendon section until operative exploration In practice tendons may sometimes be incompletely severed These will pass the clinical tests enumerated but their remaining fibres may later rupture This is an added reason for emphasis on exploration as the final test

Tests of Nerve Function

Nerve injuries are more frequently overlooked than are tendon injuries The explanation of this usually lies in improperly executed tests of sensation or movement. Tests of nerve function are mostly subjective and an upset patient may be unreliable They are of little value in young children.

Tests of Motor Function must be carried out with due regard to common variations of innervation and the compensatory effects of trick movement as described in Chapter II Many of the trick movements which have been described raise no clinical difficulty if due precautions are taken to observe or control movement in proximal joints

It must also be remembered that nerve trunks may be incompletely divided and that the absence of nerve function in recent injuries does not necessarily mean complete anatomical discontinuity in a nerve

Ulnar Nerve.—With the fingers straight they can generally be adducted and abducted to and from the middle finger only if the ulnar nerve supply to the interosseous muscles is intact. This is a most reliable test of ulnar nerve motor function provided that throughout the test neither flexion nor hyperextension is permitted This can best be ensured by placing the whole hand palm down on a flat surface Even with these precautions, however most reliance should be placed on the capacity of the middle finger to abduct in either direction or the capacity to adduct the little finger This is because the extensor communis and the extensor indicis proprius can respectively sometimes abduct and adduct the index finger while the extensor communis may adduct the ring finger and the extensor digiti minimi can be a strong abductor of the little finger If the adductor pollicis is not functioning, the tip of the thumb cannot be brought across to the base of the little finger maintaining contact with the palm in transit except by flexing the interphalangeal joint of the thumb with the flexor pollicis longus

There are many variations of these tests but all have a common basis

Median Nerve.—If the short abductor of the thumb is paralysed the patient cannot lift the thumb clearly forward in a plane at right angles to the plane of the extended hand The patient can be asked to touch the examiner s fingers held in appropriate position The short abductor can be seen and felt to contract if it is functioning. (The occasional variations of innervation of the thenar musculature as described in Chapter II must be remembered)

Tests for Sensory Function.—The clinical test of sensation should be that of light touch carefully applied by a non-rigid object in relation to all suspected areas. This is best carried out with a wisp of cotton wool or a fine camel-hair brush. Each main nerve and each nerve branch has a specific area of cutaneous sensibility. In the case of the median and ulnar nerves the delineation of specific areas of sensory loss follow a clear-cut line down the centre of the ring or sometimes the middle finger. In the case of injuries to their digital nerve branches, however, areas of absolute sensory loss are small and easily missed. If more than light touch is used or some rigid object is used for testing, fallacies associated with movement of joints or deep-pressure sense arise.

Tests for Bony Injury

Our main concern in this book is with open injuries where the extent of bony damage is usually obvious and will be noted at the exposure of the operative procedures. Nevertheless in a proper organisation an X ray can and should be taken through dressings and first aid splint without upsetting the patient. It may give some forewarning in regard to method of fixation. It does not show such important things as exposure of bone or open fracture sites, the soft tissue attachment of fragments or other considerations of viability. It is not good practice to disturb dressings and first aid splints for unnecessary routine X ray examination.

In the case of closed injuries, however, which may not necessarily be subjected to surgical exposure, X ray examination is always indicated when fractures or dislocations are suspected. In addition to study of displacements it is especially important to determine the relationship of bony injuries to any joint. Joint involvement by fractures has a singular prognostic significance and influence on the management relative to other structures. Details of clinical signs of closed fractures are well covered in many standard textbooks, and the hand does not call for any particular study of these.

The General Examination of the Patient

General systematic examination must never be omitted, not only in relation to other possible injuries which might have been received but in relationship to fitness for any general anæsthetic or prolonged operation.

Some Common Mistakes

Certain common mistakes in the clinical examination of recent hand injuries are listed for emphasis.

1. Median Nerve Injury.—It is surprising how frequently a penetrating wound involves the median nerve in its vulnerable and central position as an isolated injury which is not diagnosed. This is usually because in testing sensation, especially with partial nerve lesions, it is done with the crude touch of the examiner's finger and to the house surgeon's question "Can you feel

that? the answer is "Yes" It is then inferred that the median nerve must be intact and so a crude clinical test outweighs the presumptive evidence of a median nerve lesion from the site of injury

2 Digital Nerve Injury —These, too are frequently missed again for lack of care in testing sensation That on the medial side of the thumb is often cut along with the flexor pollicis longus when a bottle top breaks while being opened It has a small and relatively inaccessible area of absolute sensory loss which is easily overlooked unless carefully and specifically tested

3 Section of the Flexor Profundus beyond the Insertion of the Sublimus.—This is easily overlooked if casual examination is concerned only with flexion of the finger as a whole and is not directed to the study of specific movements at individual joints by controlling proximal joints Relaxation following full extension can be mistaken for active flexion

4 Cut Flexor Tendons and Nerves at the Wrist —The extent of damage is frequently under estimated

5 Cuts of the Central Slip of the Extensor Expansion —These are a common injury which again must be diagnosed on the presumptive evidence of a wound in the region of the first interphalangeal joint. The deformity and disability of the finger which result are not obvious for some time because extension of the proximal interphalangeal joint is achieved with simultaneous hyperextension of the distal joint by the activity of the lateral elements of the extensor system This capacity is in time lost as the lateral slips prolapse sideways until they can no longer extend the proximal interphalangeal joint and, indeed aggravate its increasing flexion deformity

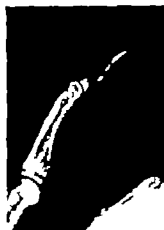


Fig. 29

Intra-articular fracture

Radiograph in a case of avulsion of the extensor tendon insertion showing the typical chip fracture which is commonly associated with this injury

6 Small Intra articular Fractures in relation to avulsion injuries of the extensor tendons at the distal interphalangeal joint will be missed if their likelihood is not realised Closed injuries of this type should be X rayed as a routine, for the treatment and prognosis is much affected by such fractures (Fig. 29)

7 Tendon and Nerve Injuries in Children —Unless tendon injuries are presumed with all likely wounds in children they will continue to be missed. The onus of proof is on the surgeon, and the inconclusive evidence of any test must always be subjugated to that of his own eyes at operation

THE CONSULTATION

A tentative plan of management should be elaborated as the result of the pre-anæsthetic examination with the optimum result for the patient in view The end result of judiciously applied repair methods must be clearly envisaged from the start with its full implications on management, time and risks all

duly considered. If any consultations are indicated this is the time for them, and all members of the team should be present at this stage. Multiplicity of *reduplicated examinations by successive individuals* is to be deprecated. Consultation implies some explanation to the patient and the sympathetic hearing of his views. If fit he should know what operative procedures are envisaged and the time factor which is involved. He should certainly be informed of the implications of any plastic procedures which are anticipated. Nothing is more disconcerting and frightening to a patient than to recover from an anæsthetic and find his hand sutured to his abdomen, or to notice, without warning, that it is his abdomen and not his hand which is painful.

If the patient is in a fit state of mind he should know the prognosis so far as it can be safely and satisfactorily given. His reactions might well influence the choice between alternatives. One patient might with good reason sooner have a finger amputated than submit to any prolonged plastic procedure if there is any question of doubt about its result, whilst another might equally well take the opposite view if not consulted. Either case could take umbrage at either action and be ready to lay blame on his management.

Frequently, however, the patient is hardly in a fit state to give detailed consideration to these matters. Then it is part of the surgeon's job, having ascertained all the facts, to make the best decision for him. The most satisfactory state of affairs is when a confident patient says "I'll leave it to you, sir, to do what is best."

In either circumstance the goodwill of the patient is a prime attribute to successful treatment. It is always better and more easily obtained at the outset.

PART TWO—CHAPTERS V TO VIII

PRIMARY TREATMENT

INTRODUCTION TO PART TWO

THIS section contains the main purpose of the book It is to emphasise not only the opportunity for primary reparative surgery but also the *surgical obligations which go with this modern trend. If* primary repair is correctly applied the need for much secondary repair as detailed in later sections is largely obviated—to much advantage. This era of primary not secondary reparative surgery can only succeed in its more general application by thorough appreciation of its hazards as well as its advantages and by the highest standards of its technical application

No excuse is made for taking " the hand as both pretext and example for developing general thoughts and principles which can equally well be applied to injuries elsewhere They may frequently apply also to many non traumatic lesions. Principles can often be better established in a specific application than in vague generality

If Chapter VI perhaps reads like a digression into Principles of Plastic Surgery this, too is inescapable The basic understanding of the elements of flap design is essential if details of specific application or methods are to have any meaning. *We can achieve nothing by the mere use of a method in* this type of work without precise knowledge of what the method can achieve and how it does so It is not the method but the application of the method which is all important It might further be asked why we have detailed the elementary approach to local flap design without a similar detailing of other methods. This is because we find it is this aspect of plastic repair which is less generally understood and thus more commonly misapplied Only guiding principles of flap design are covered

Verbal explanation is difficult and there is much danger in suggesting standardised procedures for universal application by two-plane diagrams, when there are such wide regional variations as blood supply and tissue thickness It is the most effective design and application of local flaps and rearrangements which mark the experience or aptitude of the plastic surgeon—not the deft execution of some mere routine procedure.

CHAPTER V

GENERAL CONSIDERATIONS OF PRIMARY TREATMENT FOR OPEN HAND INJURIES

ANÆSTHESIA

NO open hand wound can be subjected to proper surgical management without anæsthesia Unsatisfactory anæsthesia or compromise in anæsthetic method makes for mediocrity in results

Any review of anæsthesia in relation to a particular region or problem of surgery to-day is likely to be carried away by the remarkable advances and achievements of modern anæsthesia in general Because a particular innovation whether of agent or method of administration raises great hopes in the solution of a particular problem it can be too readily applied in a routine way The indiscriminate replacement of the old by the new should not be considered without sound reason or obvious advantage The past ten years have been illuminating in this regard and anæsthesia relative to hand surgery will be discussed from this viewpoint.

The requirements of this field do not call for elaborate techniques The patients in general are healthy subjects, and our main concern is what anæsthetic methods facilitate the best surgery Special arrangements for a poor risk patient are an exceptional requirement. The essential adjuvants to good hand surgery are few They include a very still patient throughout an operation which may be prolonged Anæsthetists must appreciate that a time-consuming dressing is often an essential part of the operative procedure It is not helpful to have a patient waking up or moving abruptly during this phase There is no demand for rapid restoration of consciousness, especially if this includes any temporary excitement or restless stage It is little reward for the tedium of an intricate repair if unco-operative movement and strain disturbs dressings or fixations suture lines or plasters not yet rigid

The choice of anæsthesia must be influenced by the nature of the surgery envisaged and it is important therefore that the anæsthetist consult the surgeon before commencing the anæsthetic. It creates an awkward situation for example if the surgeon finds that a patient on whom he elects to do an abdominal flap attachment has already been given a brachial block anæsthetic Moreover the anæsthetist s activities have much bearing on the amount of bleeding throughout an operation He should be just as aware as the surgeon of the setbacks which follow excessive bleeding and hæmatoma accumulation Unnecessary bleeding during and after operation can often be associated with wrong choice of anæsthetic or its technique of administration. Except in a few particular cases there is no excuse for the use of agents or methods which the surgeon associates with abnormal bleeding in operative wounds The reason for this may well be changes in blood physics and chemistry as yet undetermined Common surgical observations cannot be lightly brushed aside. Having watched an increasing application to hand surgery of closed circuit anæsthesia

as developed and applied in other fields it is our opinion that the hazards of increased bleeding and hæmatoma accumulation are increased by this technique This has not been developed by election but by necessity with the use of new agents Erratic unpredictable, and variable degrees of bleeding in the operation field contrast unfavourably with the state of affairs noted during an era in which simple ether anæsthetics were almost exclusively used by our anæsthetists. It contrasts poorly also with the state of affairs when local or a regional block anæsthesia is used

It is in relation to these particular requirements of anæsthesia which are of special advantage in hand surgery that the following review of techniques in current use in the unit is given.

General Anæsthesia is required for most severe hand injuries where any extensive reparative procedure is anticipated or where parts other than the hand are involved such as abdominal or cross-arm flaps

Experience has shown that bleeding is more difficult to control with certain techniques and agents notably closed circuit methods controlled respiration with the use of relaxants and with cyclopropane. These apply whether or not a tourniquet is used for bleeding, difficult to control often continues long after tourniquet release Moreover a post-operative restless stage after cyclopropane is embarrassing to reparative procedures

In public hospital practice for student teaching purposes ether administered by the open method is extensively used and gives good and safe operating conditions Other techniques involving spontaneous respiration nitrous oxide and ether nitrous oxide and Fluothane do not cause undue difficulty with hæmostasis in this regard Fluothane is perhaps preferable. General anæsthesia for children is usually induced by sodium thiopentone administered rectally A 10 per cent solution is used and the dosage estimated on the basis of 1 g. of thiopentone per 50 lb of body weight This is particularly useful if the child is to be subjected to repeated operations for repair Induction with intravenous sodium thiopentone is used if the child is of an age to tolerate the injection In either case induction is followed by the open administration of ether

SODIUM THIOPENTONE is used in the induction of all general anæsthetics but has very little place as the sole agent for any but very minor procedures. Sudden impulsive movements of the limb often occur in unpredictable fashion. Owing to its lack of analgesic properties too large a quantity is required for operations on such a highly sensitive region as the hand

HYPOTENSIVE TECHNIQUES are not used for operations on the hand because safer methods give satisfactory operating conditions and it is not easy to obtain the required elevated posture of the limb

Regional Anæsthesia.—Brachial plexus block is used extensively for hand injuries where no other part of the body is likely to be involved in the reparative procedures It gives excellent operating conditions and peaceful immediate post-operative period In cases where the injury to the hand occurs soon after a meal it is the method of choice

PRE-OPERATIVE medication includes omnopon ($\frac{1}{3}$ gr) atropine sulphate

($\frac{1}{100}$ gr) one hour prior to operation and if circumstances permit, a barbiturate such as nembutal is included at least two hours beforehand It has been found that the use of atropine diminishes the incidence of vasovagal disturbances following the block

Xylocaine is the agent most commonly used owing to its quick and reliable anæsthetic action Amounts up to 40 c c. of 1 per cent solution with adrenalin 1 in 400 000 may be used and this will produce anæsthesia for periods up to three hours

With the more experienced members of the team the percentage of failures is small and when there is only partial success individual nerves may be blocked to produce the desired result

The actual technique of injection used is that outlined by Macintosh [1]

COMPLICATIONS —These are few and this incidence varies with the skill and experience of the operator In some of our cases (1) pneumothorax and (2) brachial neuralgia have occurred

1 *Pneumothorax* —Provided this is detected early before the patient is ambulatory the pneumothorax has resolved quickly without undue inconvenience to the patient provided there is no underlying pathology The incidence of pneumothorax diminishes with the increasing experience of the operator and can be minimised by using the shortest possible needle

2. *Brachial Neuralgia* —In one instance the patient suffered a severe neuralgia lasting three weeks—others have had less severe pain for periods up to some months. The incidence of post injection neuralgia can be diminished by (*a*) the use of fine gauge needles—never greater than 23 gauge (*b*) less persistent efforts to obtain paræsthesia during the injection These precautions lessen the chances of trauma to the cords of the plexus

Local Anæsthesia has an invaluable place in hand surgery With proper technique and if some contraindications are respected it is effective and devoid of risks The following principles must be emphasised in its use (1) Discrimination must be exercised in the quantity and type of solution used Each surgeon may develop his own standards. Nevertheless, he should fix an upper limit to the amount of any solution he injects and keep to his familiar preparations and standards, bearing in mind the safe maximum dosage for each individual drug. (2) Adrenalin should never be used in the solution, because its vasoconstricting influence (in addition to the mechanical constricting effect of any injection) may adversely affect the viability of a part. In any case it obscures the clinical criteria of tissue viability (3) Local anæsthetic should be used only for recent wounds and never if infection is present or suspect by time lapse or the nature of the wound (4) Patience is a necessary adjunct. Many local anæsthetics are regarded as failures or too much solution is used because an impatient surgeon aims to finish an operation when the degree of anæsthesia is barely fit for him to commence

LOCAL INFILTRATION ANÆSTHESIA has a very limited place for hand injuries It is permissible in clean recent wounds where only closure by direct suturing

[1] Macintosh & Mushin (1954) *Local Analgesia Brachial Plexus* 3rd ed Edinburgh Livingstone.

is indicated. Under these conditions there is minimal risk of spreading infection, less risk than the gain resulting from proper wound cleansing and closure which cannot otherwise be ensured The needle should be inserted clear of the wound through a prepared skin area and with due regard for the direction of nerve supply Only the minimal effective quantity of solution should be used

LOCAL BLOCK ANÆSTHESIA is very useful for some wounds of the fingers Its dangers have been rather over-emphasised without reference to the method of its use If a maximum of 2 c c of local anæsthetic is injected carefully into the region of each digital nerve proximal to the base of the finger (Fig. 30), if the finger is held over the flexor tendon sheath region to make sure the injection is not made into the sheath if adrenalin is never used, and if the surgeon is patient enough to wait sufficient time after the injection good anæsthesia is generally obtained No undue tension is created by this method and there is therefore no interference with the vascular supply to the digit. The dorsal digital nerves must also be blocked for work proximal to the end joint If, after reasonable time lapse there is failure of the block anæsthesia, it is better to supplement this than to institute any indiscriminate supplementary injections about the wound regions.

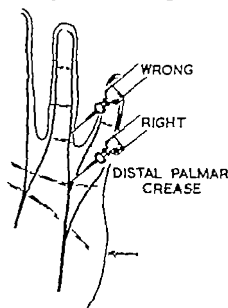


FIG. 30
Site of injection for local block anæsthesia of a finger
The injection should be made well proximal to the base of the finger The common volar digital nerves bifurcate at or proximal to the distal palmar crease *i.e.*, near the level of the metacarpo-phalangeal joints.

We have had no cause to doubt the safety of local block anæsthesia if these desiderata are satisfied. The occasional catastrophe of local gangrene of a finger can generally be ascribed to neglect of one or more of these obligatory conditions (Fig 31)

Anæsthetic Recovery.—Due attention to the anæsthetic recovery phase obviates many early complications of operation

Restlessness or struggling must be prevented In this respect the recovery from pentothal is good the excitement following cyclopropane is bad Intravenous omnopon ($\frac{1}{3}$ gr) given by the anæsthetist before the patient leaves the theatre generally guarantees immunity from these effects In procedures involving flap attachments and migration it is essential that the patient be constantly closely and competently attended until fully co-operative Any man handling must respect the procedures carried out It is the surgeon s duty to complete all dressings and fixation arrangements and the nurse s duty to see that these are maintained The less discontinuity there exists between these two personal responsibilities and the less the patient is handled or transferred the less the risk For this reason we do not favour the modern trend for interposition of special recovery arrangements between operating theatre and ward



FIG 31

Gangrene of finger—following the injection of local anaesthesia

The distribution of gangrene is strongly suggestive of vascular occlusion with failure of collateral compensation. Dissection of the amputated finger in this place disclosed marked constriction in the whole length of the main vessel on that side as compared with its opposite number No lumen was apparent. The basis of this condition is a matter of interesting conjecture as we can divide a main digital vessel without harm. Some combination of factors apparently prevents normal collateral response The fact remains that such catastrophes do happen.



FIG 32

Cleansing of the limb

An essential preliminary to operation. The damaged area of the hand is covered by a sterile pack while all the remaining area is thoroughly and repeatedly washed with soap and water With proper arrangement only one pair of hands is necessary

CLEANSING

There are two considerations in the cleansing preparations that of the part and that of the wound itself

Cleansing of the Limb or Part exclusive of the Actual Wound—This should include the whole area which might be concerned in the use of a tourniquet, in selection of a skin donor site or in any other possible manipulation by the surgeon This can be well and conveniently done by the assistant After careful removal of first aid dressings and splints a thick gauze pad folded to appropriate size is held over the open wound by the left hand. The whole limb supported if necessary over a splash bowl containing soap and warm water or other detergent is rubbed vigorously and with repeated lathering for a period of not less than five minutes (Fig. 32, A) This preliminary preparation is carefully carried right to the skin edges of the wound and when completed the limb held down towards a bucket is sluiced from a jug of saline (Fig. 32, B) By removing the gauze pad from the wound it, too can be included in this mechanical lavage. The cleaned area is then swabbed with a watery solution of a suitable antiseptic and the patient and part towelled up as for an elective operation on the hand

Cleansing of the Wound Itself—This must be accomplished thoroughly but without being rough by procedures varied to circumstances Antiseptics are not used in the wound itself—they are harmful and unnecessary Forceps are used to remove obvious foreign bodies or other contaminants The wound surfaces may be wiped with dry or wet saline swabs A rubber bulb syringe may be useful

All ramifications of the wound must be visualised and explored. Particular care is necessary in injuries which might involve the presence of broken glass, road particles or other foreign bodies Formal and complete excision of hand wounds is not practised Ragged edges are regularised by trimming with fine scissors Otherwise only obviously devitalised and contaminated tissues are excised together with the removal of any masses of blood clot

All removed debris is carefully deposited in a receptacle which with the instruments used at this phase of the procedure is then removed from the field of operation.

FINAL ASSESSMENT OF DAMAGE

Thorough exploration of the wound gives the opportunity for a final assessment of damage which is necessary to proper selection of procedure

This detailed perusal should include visual inspection of all ramifications of the wound which can now be purposefully and carefully retracted in a way contraindicated before operation in the unprepared wound The necessity for this inspection cannot be over-emphasised

Study of hand posture under anæsthesia when the hand lies so typically in the relaxed position gives opportunity for confirmation of pre-operative observations

Is there any Loss ?—The diagnosis of skin loss must be carefully considered This is easy in gross cases, but minor grades of skin loss are frequently over looked Such misjudgment is a common cause of mismanagement, for it is the degree of skin loss which largely determines the optimum method of wound closure. Even a small area of skin loss on the hand may be relatively important. Conversely skin loss is often diagnosed where none exists because of hasty examination or failure to appreciate the normal retraction of any open wound When any surface breach is made, except in few circumstances and odd situations, the resulting wound gapes, *i e* the wound surfaces separate The amount of separation depends on many factors the situation size and shape of the wound its axial direction relative to normal skin tension lines, the particular structures involved and the amount of tissue loss, if any To these factors must be added the effects of subcutaneous hæmorrhage tissue damage and œdema. Such influences are exaggerated by time lag dependent posture or inadequate dressing, so that they may indeed, constitute the main basis of wound-gaping. Thus a wound gapes, whether or not it is complicated by tissue loss Only the closest scrutiny and comparison with normal anatomy, therefore, will prevent mistakes in diagnosis Only by purposefully assessing these factors in every case can the examining eye be trained. Is there any tissue loss ?—Of what degree and of what tissues ?

What Structures are Exposed ?—Any exposure of deep structures devoid of their normal coverings should be noted, especially tendon devoid of sheath or bone shorn of periosteum or normal soft tissue attachments. Absence of skin cover to such exposed structures should be especially noted

Will the Skin Survive ?—The viability of all flaps undercut or only partly attached must be carefully considered The modern practice of primary wound closure makes this decision paramount, for closure with non viable tissue means failure and closure over non viable tissue may be disastrous. When assessing viability one should note oozing or bleeding from cut edges, the colour and circulatory return after pressure on the skin, and the shape, dimensions and attachments of any flap in relation to blood supply Skin flaps which have been severely compressed no matter what their appearance, should be regarded with suspicion. It is safe practice to remove them Venous engorgement in a flap, if not corrected, will pass through asphyxia livida to death of the flap from intravascular thrombosis Posture and light pressure will improve the livid flap

Doubtful flaps may be left for a time at operation to see if they improve, but if they do not they should be discarded rather than retained with optimism. We commonly hear the expression, "We did not think the flap would live but we just sutured it back in case." This type of thinking usually leads to disaster The only luck one can expect is bad luck.

What Structures are Damaged ?—Detailed inspection of all the structures in the area of the injury is the only safe method of finally establishing the extent of the damage to tendons nerves, bones and joints Pre-operative conclusions must always be substantiated or otherwise at this stage.

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CHOICE OF PROCEDURE

With any recent soft tissue wound there are two main considerations (1) The indication for closure should the wound be closed ? (2) The method and technique of closure how should the wound be closed ? Not only must *repair be correctly planned it must be correctly executed* The one is useless without the other

With *hand injuries, in addition to these decisions*, common to all wounds we are also concerned with the deep structures—if and how these should be repaired.

Indications for Wound Closure.—In general it can be stated that a wound should be closed if it is, or can be made by surgical preparation a clean wound



Fig. 33

Primary wound closure

A, Multiple finger injuries from a " buzz " plane B One week after primary closure including suture, local flaps, free grafts, and completion of amputation.

The nature of the wound the circumstances of its production the patient's reaction and outlook, the local surgical facilities or the time factor might in diverse ways render the above criterion unattainable and so contraindicate primary closure. However under average modern civilian conditions (it may be otherwise with war injuries) most hand wounds within a reasonable period of time (up to *twenty four hours*) *can be made fit to close by surgical preparation* The use of antibiotic drugs has extended the arbitrary period within which *primary closure is free of infective complication*

After wound cleansing, the main object of primary treatment is complete closure of the soft tissue wounds (Fig. 33) This applies no matter how severe the injury how extensive the tissue loss or what tedium is involved for the surgeon

To-day we are not concerned so much with the indication for primary closure as we are with the technicalities of best achieving this end So important is this that we feel it should be the *main stimulus to the segregation of all cases*

of injury under surgeons familiar with all the technical methods of repair. It is useless to spread a doctrine of primary wound closure if such closure is being demanded of practitioners or surgeons whose knowledge of method ends with the insertion of a few silkworm gut sutures. If these are the circumstances under which the principle is to be executed, then it would be better if it were never conceived. At least the sin would be only one of omission if the wound were left open after cleansing, whereas inadequate attempts at swinging flaps and burying hands or suturing over dead tissue produce some of the worst sins of commission that we see.

Details of the available methods of wound closure and the considerations on which each is based are set out in Chapter VI.

Indications for Repair of Deep Structures.—By contrast, the problem here is a varied one. Fractures and dislocations must be reduced and maintained, but whether or not tendons and nerves are repaired is a different matter. Physical continuity in these structures is insufficient—they must function. They cannot function in a mass of scar tissue, so that if the highest standard of primary healing cannot be anticipated with absolute confidence the repair of tendon or nerve is generally ill-considered at the primary procedure.

Thought and understanding of the manner in which the injury was received, its subsequent first aid and casualty handling, and its appearance in the light of one's experience are much better guides to the likelihood of primary healing than are academic considerations of time lapse since injury.

With this in mind a good working principle can be laid down if we recognise two main clinical types of hand injury, the "tidy" and the "untidy." These can be compared and contrasted not only in their causation, nature and clinical presentation, but also in the degree of success which is likely to follow their primary repair (Fig. 34).

The Tidy Hand Injury

These are typically caused by injuries with choppers, cutters, knives, axes or glass (Fig. 35 A to D). Common household injuries are usually of the "tidy" type. They present no difficult technical problem of soft tissue closure and heal quickly if carefully managed.

Skin edges are generally clear-cut, and skin loss, if present, is clearly defined. Fractures are exceptional, but tendon or nerve sections are common. In these cases primary repair of all the injured structures is indicated (with certain exceptions which shall be mentioned later in Chapter VII) provided only that there is no real likelihood of infection being already established in the wound.

The Untidy Hand Injury

These typically result from accidents with mobile machinery, power-driven saws, power presses and buzz planes, which produce severe compound hand injuries of an "untidy" type (Fig. 36 A to D). By "compound" is meant any open wound involving several tissues, not merely compound fractures. By "untidy" we mean that the soft tissue wounds are usually multiple and of an irregular nature. Skin edges are jagged, skin loss may or may not be present

Multiple fractures and complete or incomplete finger amputations are common. Tendons and nerves, though widely exposed, are not always severed It is often noted how fingers are left attached only by these structures. The chief object of primary operation in these gruesome looking injuries is the careful closure

TWO MAIN CLINICAL TYPES OF OPEN HAND INJURY

	The Untidy Hand Injury	The "Tidy" Hand Injury
1 COMMON CAUSES	Mobile machinery e g power saws and presses, buzz planes	Household type accidents with blades and other cutting edges.
2. NATURE—		
(a) Surface wounds	Usually multiple, irregular and jagged avulsions common	Usually single and clean cut.
(b) Fractures	Commonly multiple and comminuted.	Uncommon
(c) Tendon and nerve	Gross exposures common but frequently not divided	Frequently cut
3 PRIMARY HEALING	Problematic.	The rule.
4 MANAGEMENT—		
Appraisal of damage	Often can only be determined at operation	Can be determined before operation
Use of tourniquet	Contraindicated	No contraindication.
Primary operation	Reduce fractures and dislocations Close all soft tissue wounds Plastic procedures frequently needed	Repair tendons and nerves Soft tissue wounds easily closed
Secondary operations	Repair tendons and nerves. Reconstructive procedures often called for	Not generally indicated

FIG 34

of all soft tissue wounds This includes the trimming and closure of any traumatic amputations. With untidy hand injuries however ideal soft tissue healing by first intention cannot be guaranteed

Though fractures and dislocations should be reduced at this stage the tendon and nerve injuries are generally better left for repair at a secondary operation. Adequate skin and fat cover for all such areas must be provided at the primary operation whenever possible. With these untidy" injuries,

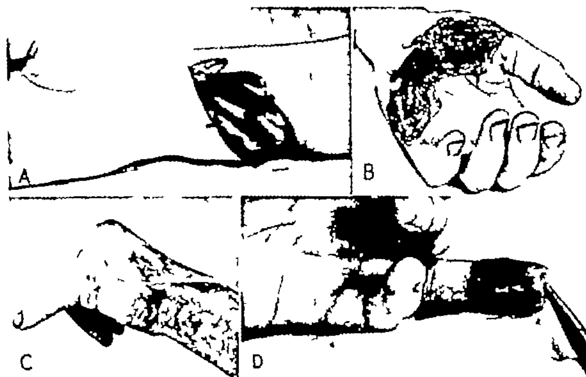


FIG. 35
Typical " tidy " hand injuries.

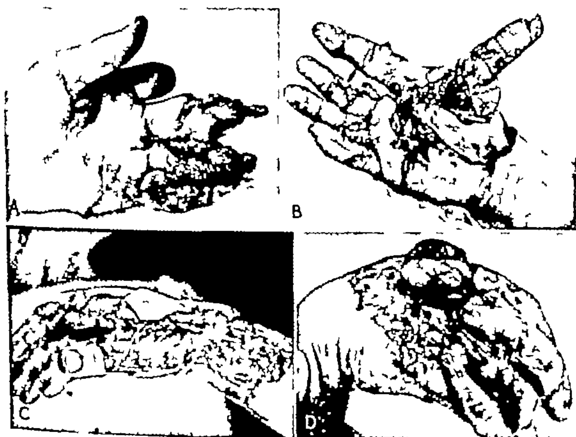


FIG. 36
Typical " untidy " hand injuries.

it would be unwise to enlarge wounds or to make further incisions as are usually indicated for effective tendon repair Moreover the after treatment of a sutured tendon is generally incompatible with that of a fracture unless some form of absolute internal fixation of the fracture can be carried out

THE USE OF A TOURNIQUET

Indications —The judicious use of a tourniquet in hand surgery has been one of the main contributions to the improvement of technique in hand repair With " tidy " injuries, where repair of deep structures is undertaken, it is essential that a tourniquet be used if repair is to be done with the technical finesse essential to success A tourniquet also helps to ensure that there is no secondary damage to other structures at operation It is fortunate indeed that it can be used with safety in just the wounds where it is indicated

With untidy injuries however the reverse applies A tourniquet during operation should if possible be avoided for we have to assess the viability of skin edges and flaps Moreover this viability may well be jeopardised by any long period of tourniquet avascularity

Technique of Application —We have found a light Esmarch s bandage, 2½ in wide most reliable as a tourniquet and to exsanguinate the part This is a much lighter type of rubber bandage than is generally used for the lower limb For children a still smaller variant of this is used For operations confined to the fingers a flat rubber band pulled taut and held with forceps at the base of the finger is a convenient form of tourniquet.

It should be emphasised that the surgeon not the dresser applies and removes the tourniquet and for this reason we use a sterile bandage It is applied after preparation of the limb and not before In the safe use of a tourniquet the tension of application is certainly no less important than is the duration of application *Tension should be just sufficient and no more than is* required to overcome the arterial blood pressure. We generally limit the use of the tourniquet to periods of one hour There are occasional reasons for its reapplication We repeat that unnecessary tension within arbitrary time limits is no less dangerous than prolonged use at correct tension The tourniquet is applied evenly and carefully up the whole length of the limb remembering that superimposed turns about the arm have a cumulative effect The tourniquet is then unwound from the bottom until only a few turns of rubber bandage are left spread over a wide area on the upper arm The bandage is only lightly stretched during its application and only a light pressure over a wide area of the arm is the object The bandage must not be allowed to double up or wrinkle, especially next to the skin

An inflatable cuff is widely used by many We regard it as a more cumbersome method, not applicable by the surgeon himself in the sterile field The dangers of the Esmarch bandage have been given undue prominence without reference to its personal and careful application by the surgeon An inflatable cuff carries no less risk if incorrectly applied and we have seen severe paralysis following its use

HÆMOSTASIS

In wounds properly cleansed hæmatoma is the greatest danger to the optimum prospects of primary closure. Even if infection of hæmatoma does not ensue normal first intention healing is precluded by separation of surfaces in the depths and ramifications of the wound. Hæmatoma is always replaced by fibrosis. Prevention of hæmatoma without the flouting of atraumatic technique requires certain practical precautions as follows —

1 Hæmostasis is necessary for exploration and procedure It is attained by mosquito-type hæmostats carefully applied to obvious bleeding points

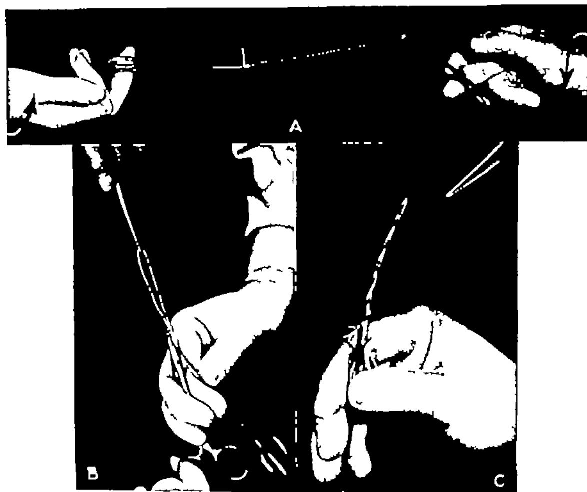


Fig. 37
A silkworm gut twist drain—how it is made.

Many of these will require no more than clamping, and in some cases twisting, before the hæmostats are removed It is better to spend a little time and patience in using packs and light pressure than to use unnecessary amounts of catgut or coagulating agents in the wound It is only necessary to tie obvious arterial vessels and other points which continue to bleed after hæmostats have been removed or twisted off Ties should be made with finest catgut and cut short. If a tourniquet has been used, hæmostasis should be

effected after the tourniquet is removed with due allowance for the temporary and reactionary engorgement which follows. This holds good even if a tourniquet is reapplied for final stages of procedure We sometimes use adrenalin (1 in 1,000) on small gauze pledgets to control persistent ooze in some areas, but except perhaps in emergency have found no necessary place for the various coagulating agents now available

2. Drainage is sometimes necessary where good hæmostasis is difficult or doubtful Twisted silkworm gut drains are adequate to separate skin edges sufficiently for capillary drainage. These have been well described by Kilner as a simple surgical commodity insufficiently popularised [1] (Fig. 37)

3 Immediately before the dressing is applied any blood collection is expressed by compression of the hand or rolling the blood out from the wound, especially from under any flap or free graft. Drainage holes are often stabbed in grafts and sometimes clot shreds are washed out with a syringe when any long time has been expended in suturing wounds or graft margins.

4 The universal use of a deftly applied light pressure dressing will control any bleeding for which a tie was not indicated and provided it is ensured that surfaces are free of blood clot, it will prevent any further accumulation

Now that sepsis can be controlled, the *bête noire* of plastic surgery in general is tension hæmatoma The hand is certainly no exception to this. Death of skin suppuration delayed healing, swelling and œdema, prolonged induration fibrosis, joint and tendon fixation and pain are but some of a train of sequelæ often instigated by blood accumulation Hæmatoma and its pernicious complications are found only in wounds hastily or haphazardly closed with imperfect hæmostasis and a surgeon s uneasy conscience.

PRIMARY DRESSINGS AT OPERATION

The dressing is an integral step of any operation Details of dressing technique are too often neglected or improperly appreciated especially in relation to the mechanical objects of dressing. Modern writings and practice have rightly accentuated the bacteriological aspects of dressing technique but unhappily too often have neglected the mechanical requirements.

Every dressing should be applied with purpose It fails if it does not properly achieve its object This can be analysed as follows (1) To control bleeding and prevent hæmatoma formation (2) To control œdema caused by reaction to injury and impaired circulation in the region (3) To improve embarrassed circulation by preventing venous engorgement in flaps and wound margins A light elastic pressure dressing applies some measure of peripheral circulatory resistance. (4) To aid or effect immobilisation (5) To absorb serous exudate or blood (6) To prevent access of secondary infection (7) To subserve certain specific functions such as pressure fixation to grafted areas

In respect of these objects, certain agents and methods are advocated

For General Use In Relation to Sutured Wounds and Flaps.—(1) A single layer of petroleum jelly gauze applied to wound areas prevents adhesion of outer

[1] Kilner T P (1941). The treatment of facial war injuries. *Med Pr* 205 5302

dressings to wound edges or to sutures and permits escape of exudate It fails in its purpose if many layers are applied with occlusive effect (2) Cotton gauze, prepared and used in multiple flat layers without rucking, suitably folded to appropriate shape, is then packed over the wound area This should be applied according to the contours of the area, using more bulk in a concavity than on a convexity In addition to its absorbent effect it thus serves as a medium for even distribution of pressure from the outer bandage to the wound region (3) Good quality light crepe bandages are used with advantage on all hand wounds Some degree of external pressure facilitates optimum healing These bandages can be cut and rolled in convenient lengths, ranging in width from ½ in to 1 2 or 3 in., for use in varying regions of the hand. Fingers should be bandaged separately Bandages, to be firm but not tight should be applied *evenly on moderate stretch, remembering that pressure increases with each turn* In the interests of economy these bandages, if of good quality, can be washed and re used, and covering them with a few turns of cotton gauze bandage prevents their unnecessary soiling.

Cotton gauze bandages cannot be used with comparable effect They cannot be adapted to contours without many twists and turns which become bulky Even single threads of cotton bandages, if caught and pulled tight may cause embarrassment to circulation They cannot achieve light elastic pressure effect

For Particular Use in Relation to Grafted Areas—(1) Tulle gras is best used on grafted areas grafts are usually spread on tulle gras, trimmed to shape and subsequently handled on it It can be conveniently stitched to wound margins along with the graft The wide mesh permits of easy exit of exudate or blood which must not be allowed to accumulate beneath skin grafts (2) Packs built up from cotton wool soaked in equal parts of paraffin and flavine (1 in 1 000) and then applied in thin layers are arranged over grafted areas to make a regular external contour for even transmission of pressure from the crepe bandage They may be supplemented by outer gauze layers.



FIG. 38

Use of the hand-stand in a dressing

Incorporation of the hand-stand in the dressing is often most helpful in obtaining even pressure over the palmar region. The disadvantages of direct round-and-round bandaging are obviated, *i.e.*, drumheading of the graft and local pressure effects over the exposed metacarpals. The bandage can be applied in many directions. A volar plaster slab fixes the wrist

In some cases, more often on the palmar surface of the hand the wool packs are maintained in position by overlying the marginal graft sutures, purposely cut long. It is best to use as few sutures as practicable as the advantages of too careful suturing are often offset by the accumulation of hæmatoma during the procedure

In view of the risk of hæmatoma and the importance of leaving a graft

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In view of the risk of hæmatoma and the importance of leaving a graft

undisturbed for some days, the requirements of pressure on an area of free graft are in practice greater than those over a flap. Differential pressure effects can be obtained by adjusting the amount of wool or gauze packing so that pressure of the bandage is brought to bear more on one area than on another.

Precautions must be taken with crepe bandages over bony prominences, especially over the sides of the heads of the index or little finger metacarpals, when bandages are arranged around the palm. The use of wool padding over these points and varying the direction of application of the bandage can prevent this. When palmar regions are grafted the hand-stand may be incorporated in the dressing to overcome these difficulties (Fig. 38). It enables pressure to be obtained on the palm without round and round bandaging of the hand itself, so obviating cupping of the palm and drumheading of the graft.

IMMOBILISATION

The natural reactions toward the immobilisation of any injured part should be assisted. It is easy to pay lip service to this major principle without respecting its practice. The importance of immobilisation for optimum healing, though universally accepted in the case of fractures, is often ignored in soft tissue injuries. All wounds of the hand are in mobile regions and all should be immobilised during their healing phase (Fig. 39).



Fig. 40

Immobilisation in the position of function.



Fig. 39

The value of immobilisation in soft tissue healing

A palmaris tendon has recently been removed from each forearm of this patient at the same operation, for use as free grafts in the right hand. This hand and wrist have subsequently been immobilised in plaster for three weeks, the left side has not been immobilised. Despite primary healing on both sides, the spreading and hypertrophy of the scar on the left side are significant of the adverse influence of early movement. The right side demonstrates the value of immobilisation during the healing phase.

There are dangers in over-enthusiasm for early function. It pays more handsomely to ensure early healing by immobilisation than to retard it by too early function. Plaster slabs accurately adapted to contours best subserve the requirements of splinting in most cases.

In the short period required for primary healing of well-closed wounds nothing is lost by immobilisation of the related joints provided that the position of function of the hand is religiously accepted and applied (Fig. 40)

In bandaging and immobilising the hand when palmar injuries have been repaired the normal transverse arch should be maintained If the palm is over flattened skin flaps may be separated from deeper planes with resulting dead space hæmatoma and delayed healing. To prevent this, it is important to prevent metacarpal movements as well as finger flexion and extension

It must be accepted that repair of tendons and sometimes nerves may require special posture and fixation These may be deciding factors in indications for primary repair where there are composite injuries They will be discussed further in relation to these particular injuries

ANTIBIOTICS AND ANTISERA

The judicious use of antibiotics as cover to surgical procedures has made unique contribution to the improved results of hand surgery It has indeed precipitated a *volte-face* change in attitude concerning the place of primary wound closure This does not mean that antibiotics can supplant or excuse neglect of accepted surgical principles It means that wound closure can be safely effected after a longer period for a far wider range of injuries and with improved overall results There is an almost complete lack of those infective complications which in the past have been the main complication of hand injuries Most infections seen to-day after hand injuries arise from neglect of trivial injuries or when the cardinal principles of wound cleansing, removal of foreign bodies or the avoidance of hæmatoma have not been respected

These facts establish ample justification for seeking every advantage from available antibiotics for each case on its merits It would be unjust to withhold effective antibiotics for prophylaxis after severe injuries or as cover to important reparative operations in deference to the prevalent thesis that antibiotics should be withheld from regular use on account of the accommodating habit of the ubiquitous staphylococcus in developing resistant strains

The choice of antibiotics will vary from time to time They will need to be given in such a manner as to give a rapid and effective blood concentration relative to the common pyogenic organisms with particular reference to the sensitivities of the prevailing strains of staphylococcus in the area

There is considerable advantage in administration by injection in the first twenty four hours after injury or operation and at present we find that a combination of penicillin and streptomycin is effective. This is continued for three to five days but if there is any evidence of the onset of clinical infection an immediate change in antibiotic cover is made If there is no response within twenty four hours of this change the antibiotic of widest cover against the staphylococcus should be given at once To delay action at this stage until material is available for culture and a pathologist s report is received indicating the infecting organism and its sensitivities, as many pathologists would have us do is to prejudice the last chance to forestall suppuration

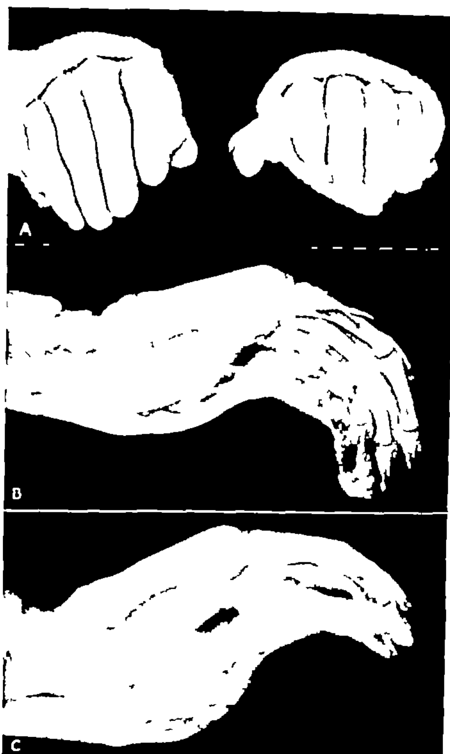


FIG. 41

A common fault during the application of a plaster slab

While the wrist is held in extension, the plaster is moulded with the mobile fourth and fifth metacarpals extended out of their true rest position with their metacarpo-phalangeal joints extended *i.e.*, the hand is flat.

A Shows the right hand in correct position, while the left hand is incorrect.
B C Lateral X-rays illustrate the same mistake B is correct, showing the varying relationship of the metacarpo heads. C is wrong. The metacarpals are all in the same flat line and the joints are extended.

Antibiotics are quite useless as sole treatment in the irreversible stage of infection where drainage of abscess or the removal of foreign material is long since indicated.

Anti tetanic serum or a boosting dose of tetanus toxoid for patients who have been previously immunised must be given in all cases of open hand injury if the slight but ever present risk of tetanus infection is to be avoided There are no really reliable clinical grounds for any discrimination of wounds in this regard[1]

Anti gas gangrene serum has no practical prophylactic application in hand injuries Non viable tissues beneath closed wounds or gangrenous flaps and amputation remnants offer the only likely basis of anaerobic infection in a region of such good blood supply We have seen many cases labelled as infective gangrene following injury because pathogenic organisms have been cultured from necrotic skin flaps In most of these however it is obvious that the death of tissue has been primary and not secondary and that the infection has followed and not preceded the gangrene

AFTER TREATMENT OF PRIMARY REPAIR PROCEDURES

Elevation of the hand should be practised in the immediate post-operative phase according to the severity of the injury For ambulatory patients an arm sling is more comfortable provided the disadvantage of over flexion of the elbow is realised For bed patients a comfortable position on pillows just above heart level is sufficient The common practice of suspending hands by bandage loops or slings from the plaster is not only unnecessary but embarrassing alike to the patient s comfort and to the local circulation Suspension as opposed to pillow rest involves localisation of pressure effects, and may well aggravate a condition which it is designed to relieve

Inspection and Early Adjustments to Dressings —All hand dressings should be inspected within the first twenty four hours of operation It should be checked that the circulation distal to any bandage is satisfactory that there is no undue blood staining of bandages, and no undue pain It is unnecessary and often wrong to take down dressings except for specific reasons as indicated by symptoms or inspection Interference without reason lays a wound open to the risks of infection and disturbance of the conditions achieved by a well applied primary dressing.

Early adjustment may be indicated to relieve bandages which are obviously too tight or embarrassing circulation. As the plaster splint usually overlies the pressure bandages, it is generally better to cut the bandages rather than disturb the plaster The area can then be rebandaged on the outside of and incorporating the slab For obvious bleeding a dressing might have to be taken right down Adjustments of pressure removal of sutures, evacuation of hæmatoma, or even return of a case to the operating theatre might be indicated

[1] The value of routine prophylactic anti-tetanic serum and the place of active immunisation in relation to recent injury are current subjects of doubt and criticism. As a result a diversity of practice is being advocated but until the facts are clearer and proper trials have been conducted we feel that current teaching should be as stated.

Within twenty four hours the ill-effect of hæmatoma can often be rectified. Beyond this it may be better to accept the situation than to interfere. Twist drains, if used, require removal in twenty four hours. Easy access to these should be made when arranging primary dressings. When patients complain of constant burning pain or throbbing in a particular local area a few turns of bandage should be cut or plaster removed to relieve pressure at that point. *It is a working rule that in such complaints the patient is always right.* Reinforcements of dressing are indicated by any blood or serous seepage to the surface. It is known that this provides a good culture medium for organisms and their easy access to an otherwise well-covered wound.[1]

Changes of Dressing are indicated for elective removal of sutures. Suture removal should always be commenced at areas of less tension at the ends of suture lines. It is wise not to remove all sutures at the same dressing. Fine eye scissors and fine non-tooth forceps are essential for the proper removal of fine sutures. In children a general anæsthetic is often necessary, in which case sutures are left a few days longer so that they can be taken out at a single procedure. *Ten per cent. mercurochrome solution is applied with advantage* by means of a swab stick, to seal suture holes and any moist or open areas of the wound.

With thick skin, as on the palms of workers' hands, the external cuticle does not unite across the wound; it peels off in time.

Pressure is always reapplied until a wound is completely healed. Soap and water is used freely to clean and soften the area and to remove macerated skin after healing.

TRANSITION FROM IMMOBILISATION TO ACTIVE FUNCTION

Wounds should be healed before movements are commenced. Early healing rather than early movement is the immediate object of primary treatment. Early movement will follow as corollary to early healing.

The duration of immobilisation, the posture and the age of the patient are important factors affecting the institution of active movement. Whether or not this transition can be materially aided by physiotherapy depends on these and other factors. It should be realised that scar resolution and return to function are normally achieved in time and often nothing more is required beyond lapse of time and the patient's own use of his hand. The normal achievements of time are often erroneously attributed to physiotherapy enthusiastically applied during this phase.

Physiotherapy and occupational therapy in routine use are unnecessary and may over-accentuate a patient's concern in his injury. A surgeon who personally encourages, assists or badgers his patient in active return to function *is often of more value than organised physiotherapy.*

Physiotherapy has its greatest place in relation to specific injuries of main structures, as will be detailed later. It must always be based on encouragement, instruction, assistance and re-education in relation to active movement. Except

[1] Colebrook, L. (1950). *A New Approach to the Treatment of Burns and Scalds.* Fine Technical Publications.

in the prevention of stiffness in joints which cannot be moved because of section or paralysis of their activating muscles, passive movements and manipulation *have no place whatever*

The indiscriminate use of lights and heat during phases of scar resolution after hand injury is to be deplored Persistent œdema, pain and stiffness often cease with the cessation of such so-called therapy Red, shiny skin is a frequent indication of such abuse.

The care of grafted areas should always be explained to a patient. These are always vulnerable to petty injuries, especially during their early existence and until there is some sensory return They are easily burnt with cigarette ends or in domestic chores Early protection may be indicated in certain occupations.

There is an unfortunate *tendency to consider rehabilitation* as an issue separate from surgical care when indeed it is part and parcel of treatment in which continuity of management has already been emphasised as a principle.

Treatment is incomplete if a patient is left in the air after its more specialised or active phases are over He may yet be unfit to return to normal activity

A wide range of psychological maladjustments through misunderstandings, compensation neurosis malingering and varied functional conditions, generally arise from failure to appreciate the common psychological reactions to injury and disability Most of them can be prevented A patient s confidence and understanding from the beginning are essential to the optimum mental and physical results of his injury The urge for early return to self-dependence must be fostered He must be instilled with the idea that his own active efforts *and outlook are prime factors in achieving this end That is the basic concept* of rehabilitation The man who is passive bored, and disinterested in his progress, though often described as a good patient is difficult to retrieve

In average cases rehabilitation is achieved without elaborate and separate organisations These may be indicated under special conditions of war time or for gross and special cases True understanding and co-operation to a common purpose between patient, surgeon and employer best fulfil the requirements of rehabilitation under civil conditions It is better not a function of special institutions [1]

[1] An interesting and valuable experiment has been conducted at the Vauxhall Motor Works, Luton, England There a special rehabilitation shop has been set up by the management where a man s normal type of work can be adapted to his disability Machine control modifications are made and the work is supervised by Mr H H Newell, who has Shop Manager status and who arranges machine modifications and adaptations on lines as indicated by the surgeons. A close-knit and friendly atmosphere prevails. There are however certain local conditions which render such a set-up practicable—the size of the works, the degree of integration and continuity which is possible in all phases of care for the injured, and a realisation by the management of values and obligations to employees beyond those of tangible financial return. After twelve years this rehabilitation arrangement has become an integral and gladly *accepted part of the works. It has had many* visitors and has formed a prototype for similar arrangements in other motor works in England and France and in both British and French National Railways. Swedish and American firms have *shown much interest in this project which* is considered applicable and advantageous for any industrial firm with over 4 000 employees. We are grateful to Mr Rainsford Mowlem and Mr Laurie Plewes for recent information about this unit.

The early assessment of result and completion of compensation arrangements are always in the patient's interest. The waiting of long periods for compensation court proceedings does not react to advantage. The British National Insurance scheme has in theory much to commend in this regard

Where it is obvious that permanent mutilation will result from any injury it is a mistake to wait until confronted with end results before ensuring that the patient realises what the limitations of his recovery will be in relationship to his previous life and livelihood It is important to visualise an end result from the start so that personal adaptation and readjustment are developed We must avoid disappointments or anticlimax by over build up of the likely results of treatment

ARTEFACT LESIONS AND "FUNCTIONAL" DISORDERS

Whatever the ideals of patient care it would be idle to by pass certain physical expressions of disordered minds These may be manifested in the





FIG. 42
Self-inflicted and aggravated wounds

FIG. 43
Secondary fixation of posture in an unco-operative patient

FIG. 42.—In this case a chronic ulcer had presented over the knuckle of the right hand for five months since an "accidental knock on the radiator of his truck" Self-aggravation was suspected, but on account of local fibrosis and persistence despite all forms of treatment, the region was finally subjected to excision and grafting with success, but the patient soon demonstrated ulcers on the left hand from "an accidental knock on a door" exposing the reason for persistence if not the origin of his initial lesion.

FIG. 43—The skin wrinkling and subcutaneous fibrosis are typical of a persistently held adduction-flexion spasm of the thumb without organic cause

instigation of wounds or in delayed healing. A surgeon who is not aware of possibilities of self inflicted or self perpetuated injuries will often be amazed or embarrassed. These problems may be revealed at any phase of treatment for any injury

Injury is one means of acquiring illness with the escape it offers, and **self-inflicted injuries** are protean They are not confined to gunshot wounds or typical suicide cuts The hand is the most likely place for a self inflicted wound easily achieved and readily demonstrated

The persistence of ordinary traumatic lesions, often trivial must in some circumstances raise suspicion The young female factory employee has in her injury a ready haven from a transient or deep-rooted psychological mal adjustment. There is no limit to the depths of deceit and intrigue to which some subjects may go The repeated surface abrasion or a lesion which does not heal as it should (Fig. 42) must be suspect. A solid plaster cast is often the best diagnostic aid in this difficult situation This is only an aid to diagnosis it is not permanent treatment for each case must be managed on proper psychiatric lines

Short of physical interference to prevent healing, passive resistance and the **absence of " the will to get better "** during the period when normal transition to active function would be expected is often no less effective in nullifying treatment. Fear of losing compensation or pending litigation are frequent causes of this attitude of mind From our knowledge of a particular injury and its treatment, and of standards of normality, it is usually easy to discern the patient who *will not* move his fingers when he says he *can not* move them They are soon found out by a few tricks of passive movement and posture These hands are often held in a typical position with the fingers flexed and bunched together If these people cannot be exposed or tricked into demonstration of their movement capacity in early stages of treatment, and if some degree of co-operation at this time is not obtained the end result might well be an irretrievably wrecked hand Fibrosis and fascial contracture readily take up the flexed and adducted position of fingers and thumb so that a wilful and persistent postural deformity soon becomes anatomically established and fixed (Fig. 43)



FIG. 44

Gangrene of the index finger three weeks after a story of injury with broken china while working as a housemaid

The finger was anaesthetic and at the suggestion of the patient it was amputated. There was a great deal of " pain and tenderness " following amputation. The region was ultimately re-explored and the stump shortened. One year later she presented with a gangrenous patch on the tip of the opposite little finger following a story of a cut with broken china several days previously Again two months later she reported with further patches of gangrene elsewhere whose nature suggested self-infliction.

Many victims of severe injury who are subjected to long periods of hospitalisation and treatment slide into a condition of moral dependency The man who has had most done for him and has been " the perfect patient can

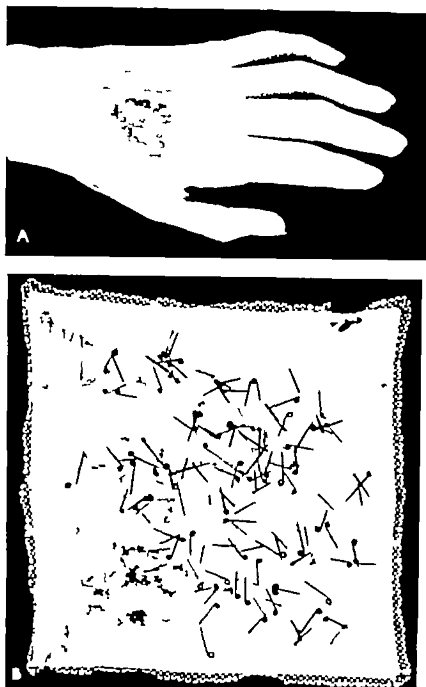


FIG. 45

A, Shows a lesion on the dorsum of the hand of a female aged 22. She had been in and out of hospital for two years with repeated ulceration on the back of the hand said to have started by a *fall on a cactus thorn*. Several "spikes" were removed *from the area on various occasions in the* subsequent weeks, and over the previous year several incisions were made for abscess, and free skin grafts of various types were done, all with the same fate. She was referred to our unit with the suggestion that an abdominal flap would be necessary. However, the history, the personality and the appearance were regarded with suspicion and a search of the girl's locker revealed a handkerchief with contents as shown in B—an extraordinary collection of cactus thorns and pieces of safety-pin. She was transferred to the psychiatrist and left the hospital soon afterwards. Eight months later a letter from another hospital, which she had apparently attended on previous occasions, revealed that she had again been submitted to a long list of investigations and a further operative procedure. *The psychiatrist considered that a long period of psychotherapy would be required for this individual,* who demonstrates that there is no limit to the extent of the deceit and trickery which such people will employ.

well become the most dependent. Awareness of this trend in long term cases is the essential basis to its prevention on the lines already discussed. He is not a true malingerer but rather the victim of circumstances which too often surround protracted management indecision and insecurity.

Excluding all the above, the true malingerer, a man who wilfully sets out to capitalise on his injury by trickery and deception, is uncommon and usually found only among those of low intelligence who believe they can "put one over the doctor".

SHORT MUSCLE CONTRACTURE

None of the conditions mentioned above should be confused with the condition of intrinsic muscle contracture (Fig. 46). This type of postural disturbance may follow any severe type of crushing injury to the palmar region but may also sometimes follow a surgical procedure for a relatively minor injury. In this latter case it seems hard to escape the inference that the fibrosis and contracture of the short muscles is the result of ischæmia and may be due to excessive tension within the wound or tight bandaging as a source of external pressure. The characteristic of this type of hand is a rigid contracture of all the short muscles often involving the thenar and hypothenar as well as the palmar muscles.

At operation the involved short muscles are found to be fibrotic and without elasticity and the only effective treatment is to divide the lateral bands of the extensor hood mechanism.

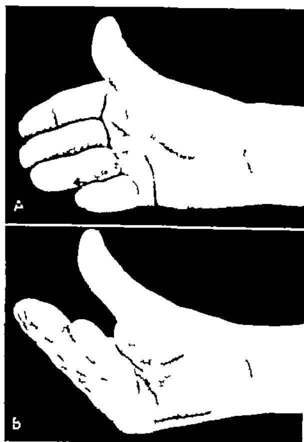


FIG. 46
Short muscle contracture following operative treatment for a relatively minor injury.

CHAPTER VI

METHODS OF WOUND CLOSURE AS APPLIED TO THE HAND

UNDER present-day civilian conditions when primary treatment of injury is promptly carried out under cover of antibiotic drugs, we are less and less concerned with the indication for wound closure we are more and more concerned with the actual method of closure

When considering the indications or contraindications for primary wound closure, the word closure must be taken in its widest sense It is not synonymous with suture.' Whether a wound is closed by direct suturing or whether some other method is adopted depends on the degree of skin loss. This diagnosis must be made relative to a particular area and to the effects of hæmatoma or œdema which may already exist in the region

For most hand wounds with no skin loss closure is easily achieved by suture but no less important are the wounds for which the same indications for closure must be met by some other method In ideal circumstances, the case for or against primary closure should not be influenced by the method which is indicated Yet time and again we still see wounds which are " left open to granulate merely because they cannot be sutured. We must confess, however that this is better than a policy of " closure at all costs " in the hands of surgeons untrained in all procedures of closing a wound

In extreme cases the diagnosis of skin loss is easy but it often takes experience to distinguish those wounds where effective closure is best achieved by direct suturing from those better dealt with by some local flap manœuvre or grafting procedure. Skin loss must be assessed in a relative sense rather than in actual amount. There are some wounds without skin loss which, because of local reaction cannot be safely closed by suture without undue and dangerous tension Conversely other wounds in some situations, despite some degree of skin loss, can often be closed by direct suture

Tension suturing is always best avoided in a field of potential infection. There can be a certain amount of tension in an aseptic wound or conversely local reactions can well cope with a modicum of sepsis in an atension wound In either case effective closure is possible Tension and sepsis in the same wound however spell failure with breakdown which could well have been avoided if the contraindication to tension closure had properly been accepted This applies particularly when skin flaps are raised whose vitality is subnormal Most failures of wound closure occur when we try to close by suture a wound where the relative skin loss indicated some grafting procedure

It is thus good practice for the beginner when in doubt as to the method of choice for the closure of traumatic wounds, to graft rather than to suture under tension It is no stigma on judgment *if the graft can subsequently be excised* and the edges of the wound after some undermining coapted with ease This is often the correct procedure

Accepting the principle of relativity in the diagnosis of skin loss the general features of the closure of hand wounds are now considered in relation to (1) suturing of wounds with no skin loss (2) grafting of wounds with skin loss

SUTURING OF WOUNDS WITHOUT APPRECIABLE SKIN LOSS

The most important attribute in hand surgery is a careful and accurate suturing technique which comes only from patience and experience Only the highest standards of first intention healing can be accepted as primary healing. This means healing in a minimum of time and with a minimum of the formative tissue reactions

Most of the advantages of primary repair of deep structures whether bone, tendon or nerves, are lost if first intention surface healing in its strict sense is not achieved Indeed failure of modern procedure is frequently seen because of failure to achieve primary soft tissue healing This produces results which perhaps do not compare with those of methods used in the past when less ambitious structural fixations and repairs were undertaken and secondary healing accepted by choice This situation must be fully realised by all who embark on methods from which the rewards of success, though great, are obtained only by highest technical standards. To this end two principles must be respected

Firstly close and accurate juxtaposition of the wound surfaces must be maintained at all points and in all planes, at least until their firm fibrinous adhesion is achieved. Mere cuticular apposition is insufficient, for though epithelial edges might be in contact there could be separation in deeper planes Any dead space so left is soon filled with exudate or hæmatoma, which in turn is replaced by granulation and ultimately by scar tissue This is not first intention healing

Secondly wound apposition must be maintained without impeding local blood supply or producing focal areas of necrosis. Diminished blood supply œdema, infection necrosis, like tension and hæmatoma are factors variously involved in a vicious circle often responsible for failure of first intention healing.

These two principles can only be satisfied by strict adherence to certain technical factors in suturing.

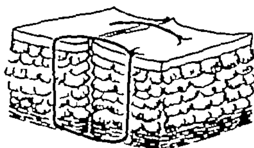
Wound edges to be coapted must be freed of damaged and devitalised areas and regularised if necessary by trimming with fine scissors

Hæmatoma is the common basis of infection. Though hæmostasis is essential, it must be achieved without large masses of foreign material and without producing devitalised areas. Unnecessary amounts of ligating material the tying of masses of tissue, or the misapplication of hæmostatic forceps must all be purposefully avoided

Atraumatic technique and accuracy in handling tissues must be rigidly observed Tissue holding forceps and heavy tooth dissecting forceps have no place whatever in wound suturing. Fine non tooth forceps delicately handled so as not to pinch skin edges, or skin hooks should be used Needles must be

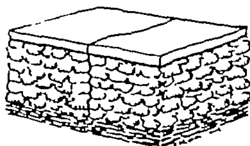
SUTURING TECHNIQUE

GOOD



parallel sutures
evenly spaced
no gaping areas
edge to edge
depth to depth
no dead space

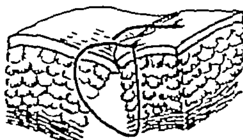
NO COMPLICATIONS



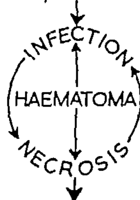
minimum scar
rapid healing

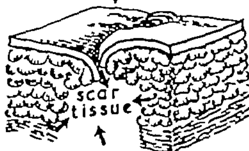
PRIMARY HEALING

BAD



uneven sutures
impaired blood supply
gaping areas
edge inverted
unequal depth
dead space





broad puckered scar
adhesion
breakdown
slow healing

SECONDARY HEALING

FIG. 47
Suturing technique.

fine and sharp (*e g* three eye curved 3/8 circle) and only fine suture material is necessary If heavier sutures are required, the wound is being subjected to undue tension True atraumatic technique implies more than a correct armamentarium—it implies also its correct and practised use Gillies has constantly emphasised this point [1]

Vertical depth apposition of a wound is best achieved as illustrated in Fig. 47 by single interrupted silk sutures inserted at right angles to the skin surface and parallel to each wound surface Using curved needles this cannot easily be achieved in a single action through both sides of a wound. Accurate skin and subcutaneous suture requires (1) Exaggerated pronation and supination of the wrist and forearm while inserting the needle in separate actions for each side of the wound, (2) practised use of skin hooks or fine forceps in correcting the retraction of subcutaneous tissue and so everting the skin edge (3) care



Fig 48
The apical stitch
An effective means of avoiding crowding of stitches and impairment of blood supply at the apex of a flap

that the depth of entrance and exit of the needle from the skin surface is the same on each side of the wound, (4) undermining of skin edges in some cases to get good surface apposition and edge eversion and in some wounds an occasional end-on mattress suture (5) insistence that the sutures cross the wound at right angles and are nowhere so close or so angled to neighbouring sutures as to embarrass circulation between them (6) special precautions in cases of angled triradiate or more complicated wounds so that no suture impedes the local blood supply Full use should be made of the apical stitch as illustrated in Fig 48 It is good practice with irregular and complicated wounds first to suture key or obvious points, such as flexure creases It is easy to missuture curved gaping wounds so that one side is sheared and buckled relative to the other To avoid this it is better to start with a few central sutures rather than at one end (7) Horizontal plane apposition in a wound, the oft neglected component of first intention healing, is best achieved by judicious use of light pressure dressing to prevent accumulation of exudate or blood in all the undercuts and horizontal ramifications of a wound This

[1] Gillies, Sir Harold (1943). Technique of wound suturing. *Clin. J* 72, 223

usually requires something more than a piece of adhesive strapping or a gauze bandage The pressure dressing has already been discussed

The proper suturing of a complicated hand wound can be very tedious. The more irregular the shape of the wound the more sutures have to be inserted. There must be no gaps in edge-to-edge apposition These are betrayed by small protruding masses of fat which subsequently die and liquefy thus adding to the risks of maceration and infection Each such protruding mass carries with it terminal nerve filaments and it is our opinion that this is the origin of many tender scars especially about the finger pulps

PRIMARY SKIN GRAFTING FOR SKIN LOSS

We use the term " skin grafting " in the broad sense to cover shifting of a skin area from one region to another It includes both the free grafting of skin in its varied thicknesses and the transfer of attached flaps of skin and subcutaneous tissue The latter may be local flaps or direct or indirect flaps from remote regions

Practical aspects of the grafting of wounds with minor degree of skin loss are better considered separately from the grafting of wounds with gross skin loss—provided again that we appreciate how skin loss is related to the dimensions and functional importance of any given area This places strict limitations on the use of local flaps even with small wounds a consideration of particular importance on the hand

Local Flaps for Wounds with Minor Skin Loss

It is frequently desirable to use a local flap to achieve part or whole of the *closure of a hand wound Such flaps when correctly used are most* valuable but incorrectly used they are procedures which can only add insult to injury There is no end to diversity in the design of local flaps but all should serve one or more of three main purposes and all are designed on one or more of *three basic principles.*

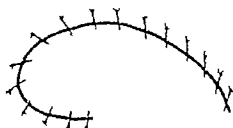
The useful purposes of local flaps are (1) To relieve tension from any important area where closure by direct suture would be dangerous or impossible (2) to ensure that a vulnerable area such as bare bone, tendon or nerve is covered *by healthy skin and a fatty plane* so that primary healing is assured and surface scar precluded from the region (3) to alter the site or direction of potential scar or tension lines

The principles underlying the design of local flaps are those of rotation advancement and " Z rearrangement

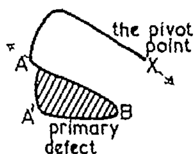
Owing to skin elasticity which varies in different regions and under many circumstances any precise geometrical design of a flap as often illustrated cannot always be rigidly applied Many procedures rely on the elasticity of the skin for their effect and this cannot be translated into straight line diagrams Except on the dorsum there is little elasticity in the skin of the hand especially in subjects such as manual workers with thick skin Moreover any

1 ROTATION

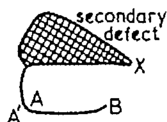




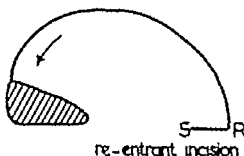
2 ADVANCEMENT



AX = A'X



3 COMBINED ROTATION - ADVANCEMENT



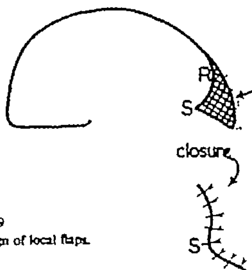


FIG 49
Principles in the design of local flaps.

flap design must be considered in relation to three planes as well as to local blood supply The safety factor of local viability is the first consideration and in raising any flap blood supply is embarrassed

The Rotation Principle —If there is a small area of skin loss, the wound can usually be sewn up in a straight line if the margins are freed from attachments and anchorage by appropriate undermining. This, however involves tension depending on the area of skin loss relative to the amount of undermining that is practicable. In practice, the latter is associated with the length of the wound If the defect is triangular or is made triangular it can be closed more easily and with less tension by a rotation flap (Fig. 49) From one or other apex of the triangular defect the incision is lengthened curving toward a line projecting from the opposite base of the defect. The length of this incision will depend on the anatomical details of the region and on the mobility and elasticity of the skin *If the flap so outlined is undermined the same defect can now be closed* more easily Provided that the midpoint of the skin margin on one side of the enlarged wound is sutured to the midpoint of its other side and subsequent sutures accordingly we now have the tension distributed over an incision much longer Skin elasticity allows some rotation of the margin of the flap and the tension caused by the skin loss is distributed over the whole suture line *This is the basic principle of a rotation flap* Though it is not often used in its simple form the principle is elaborated in other local flaps It is merely a manœuvre which distributes tension over a larger area to diminish it in any one vulnerable site. The larger the secondary incision the greater the effect in disseminating tension There is no secondary defect with a true rotation flap

The Advancement Principle —This is a means not of distributing tension but of transferring a defect from one area to another This is generally from a vulnerable to a less vulnerable area such as from that overlying a fracture site to some remote soft tissue area If properly designed an advancement flap can be sutured over a vulnerable area without tension It creates an equivalent secondary defect which can be grafted closed by further plastic manœuvre or perhaps even left to secondary intention healing. Its effect is at once lost if the margin remote from the wound is sutured back whence it came—a common mistake

It should be noted (Fig 49) that an advancement flap pivots on the point X and not the point B The prime consideration of design therefore is that AX=A X *not* that AB=A B If AX is less than A X when the flap is advanced over the defect there will be a diagonal tension line A X across the flap This common mistake jeopardises the blood supply AX can be made equal to A X either by increasing the length BA or prolonging the incision AX as indicated by the arrow near to the projection of A B

The extent of these manœuvres must be governed by overall dimensions and blood supply (Figs 50 and 51)

Combinations of the Rotation and Advancement Principles *are commonly* applied The elements of design of this flap are again shown in Fig 49 The particular feature is the re-entrant incision at the base of a rotation flap By a combination of rotation and advancement, it is then possible to close both the

wound and the secondary defect, which is a smaller triangle in the region of the re-entrant cut. The latter is closed by further local rearrangement or by suture in an opposite direction to the line of re-entrant incision. Most of the tension due to the rotation effect is distributed to this area remote from the wound

Much more skin than the area of the wound to be covered must be available before flaps involving the rotation principle can be applied with good effect.

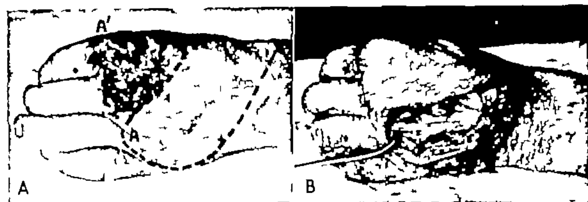


FIG. 50

A simple advancement flap on the dorsum of the hand

A, A recent injury from a circular saw with skin loss and tendon damage.

B, Shows a simple advancement flap to cover this area. The shape size and situation of the defect are suited to the use of a local flap Compare with that in Fig. 51 of this chapter The secondary defect is covered with a split-skin graft.



FIG 51

A simple advancement flap for a finger injury

A, Condition at the first dressing five days after an advancement flap to cover a dorsal area of skin loss and tendon damage over the first interphalangeal joint region of the middle finger—before removal of sutures. The graft on the secondary defect is obvious. The size of the flap for a primary defect of equivalent size should be noted. B, The ultimate result many months later—full function.

When a re-entrant cut is made at the base of a flap the blood supply must be assured The marginal incision of the flap should reach a line projected from the base of the defect to be closed at a point not less than twice the length of the base away from it. These factors strictly limit the size and site of wounds which can be closed in this way on the hand. Most of the errors with such flaps are due to design on too timid a scale Whenever this method of closure is under consideration the surgeon should ask himself " Does the area permit of the design of a flap of adequate proportion and safety for this particular

defect? In most cases on the hand the answer would be in the negative The method is used mostly on the back of the hand as illustrated in Fig 52, which shows the desirably large proportions of such a flap for a particular defect

Thus we conclude that for most requirements local flaps on the hand should generally be of the simple lateral advancement type

The triangle is the basis of local flap design so that wounds must be so

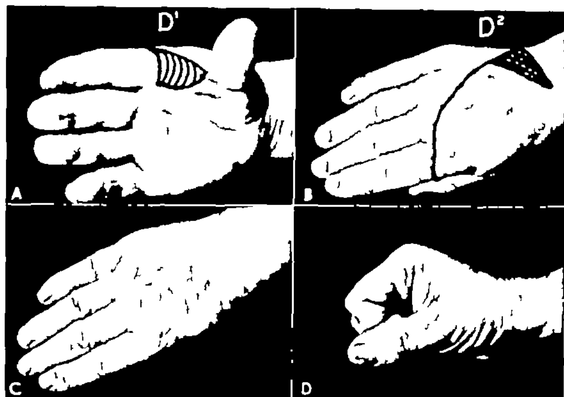


Fig. 52

A rotation-advancement flap

A, Shows the site of primary skin defect D —one of the few regions on the hand suited to this manœuvre

B Shows the outline of the rotation-advancement flap and the secondary defect D² with a split skin graft Again note the liberal design of flap necessary for this method.

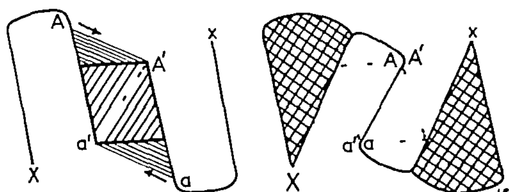
C, D Show the ultimate result with full correction of the disability absence of any secondary disability and negligible scars. There is ample skin in the thumb web.

trimmed or shaped that they are triangular or else of such shape as can be reduced to triangles. For a simple triangular defect the base of the flap should be at the narrow end of the defect and its distal margin a little beyond the widest diameter of the defect as in Fig. 49

For a quadrilateral defect (*i.e* two triangles) closure might require *two lateral advancement flaps* each with its secondary defect to be grafted (Fig 53)

For a *fusiform defect*, again considered as two triangles the two advancement flaps if made from the same side of the wound and their ends

not separated, would constitute a single bridge flap This is a common usage of the lateral advancement principle in other body regions but rarely used effectively on the hand It is a flap which is often misused and in any case




areas excised to permit flap advancement

Fig. 53
Design in closure of a quadrilateral defect
A double application of the advancement principle.

RIGHT WRONG

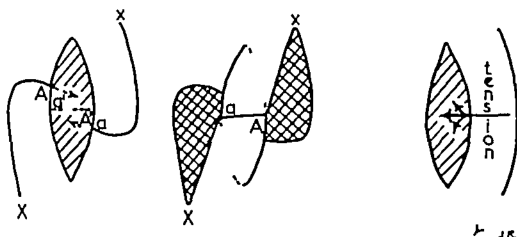


Fig 54
Design in closure of a fusiform defect
The disadvantages and limitations of the bridge flap for reasons explained in the text are obvious.

it is not sound in design (Fig. 54) because the widest portion of the defect can only be sutured under tension for the reason illustrated This objection would be reduced if the incisions raising the bridge flap were prolonged and curved as indicated but this is contrary to safe blood supply It should only be applied

to the most slender fusiform defects It illustrates well how there are always considerations other than those of geometrical design

In the face of many such factors and variables, absolute rules cannot be set down for design of local flaps for any given case of triangular defect On this understanding, the following generalities are in the best interests of safe blood supply (1) The distal margin of the flap should be just beyond the largest diameter of the defect to be closed (2) the base of the flap should be its broadest diameter *i e* it should not contain re-entrant angles (3) wherever possible, the base of the flap should be directed toward the main blood supply *i e* proximally otherwise the length of flap must be diminished accordingly (4) the secondary defects should be covered with a split skin graft.

The Principle of the "Z" Plastic—This is a special application of the advancement principle, to alter the direction of a potential scar from longitudinal to transverse and so permit a closure by some degree of tension suture which might not be acceptable in the original direction It also makes good some degree of skin loss in one dimension at the expense of the other By raising flaps on either side of a longitudinal wound it also permits of a wider access to deeper structures as is sometimes indicated in reparative procedures.

The basic design of a "Z plastic is illustrated in Fig 55 It will be seen that if transposition of the triangular flaps is to be effective the length of all limbs of the "Z" should be equal and the angles between each arm and the central limb should also be equal When the flaps are cut, the apical angle of each flap narrows whilst the defect widens. By widening the angles of the "Z," more relaxation is obtained in the axis of its central limb at the expense of transverse tension which increases with the difference in length between CD and AB The wider the angles, the more difficult transposition becomes In practice the angles should range somewhere between thirty and sixty degrees, depending on the desired effect and the blood supply of the flap This in turn depends on the site and thickness of the flap With angles beyond sixty degrees the flaps cannot be transposed and below thirty degrees CD becomes less than AB Angles of sixty degrees give an optimum effect. This means designing equilateral triangles The standard Z" plastic can be modified in many ways to serve particular requirements Sometimes the angles are made unequal sometimes the limbs of the "Z" are curved off to give rotation effect

On the hand "Z" plastics are most effective if after transposition the central limb of the Z" comes to lie in the transverse crease lines, especially on fingers. The only reason why this procedure is not more often applied in primary treatment is because most linear wounds of the hand are already in a transverse axis ... a finger are not common

It must be emphasised that the " ... the problem of skin loss over an area It can ... axis by introducing tension on the other a ... r a

formation in a non scarred area or for a contracted linear scar It often fails when skin loss, not always self-evident, has been overlooked because of scar contracture in a foreshortened area.

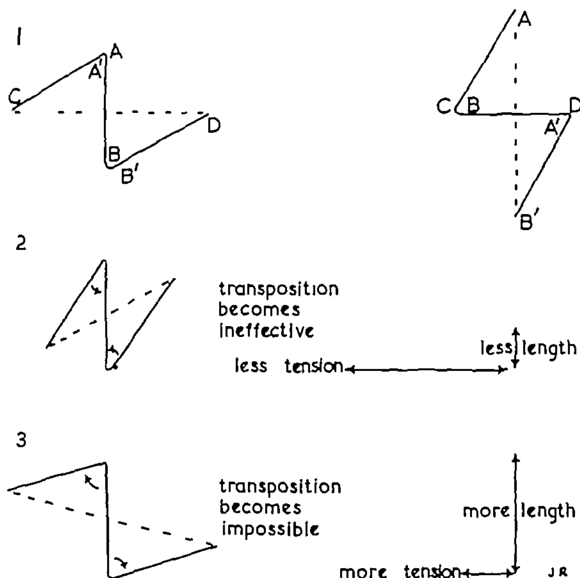


FIG 55

Design of the " Z " plastic

1 The normal design of a " Z " plastic showing the relative increase in length in one diameter AB which is obtained by transposition of equilateral flaps.

2, The effect of narrowing the angles of the " Z " so that transposition ultimately fails to attain the object of a " Z " plastic.

3 The effect of opening the angles of the " Z " so that the transposition manœuvre ultimately becomes impossible.

GRAFTING OF WOUNDS WITH MAJOR SKIN LOSS

When primary closure is needed for wounds with major degrees of skin loss, some form of skin graft is inescapable These wounds constitute two groups according to whether or not the wound is suited to the direct use of a

to the most slender fusiform defects. It illustrates well how there are always considerations other than those of geometrical design.

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It must be emphasised that the "Z plastic cannot cope with the problem of skin loss over an area It can only increase the dimension in one axis by introducing tension on the other axis It is an ideal manœuvre for a web

formation in a non-scarred area or for a contracted linear scar It often fails when skin loss, not always self-evident, has been overlooked because of scar contracture in a foreshortened area

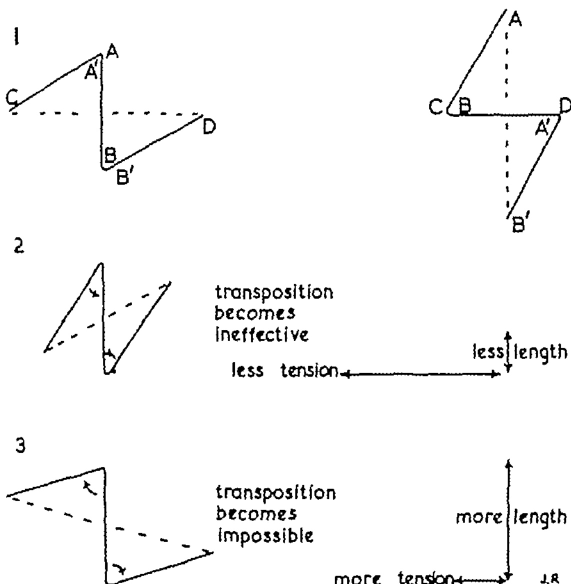


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GRAFTING OF WOUNDS WITH MAJOR SKIN LOSS

When primary closure is needed for wounds with major degrees of skin loss, some form of skin graft is inescapable These wounds constitute two groups according to whether or not the wound is suited to the direct use of a

free skin graft. The exposed tissue may be an unsatisfactory base for a free graft. A more bulky soft tissue cover than free skin may be indicated by the requirements of function or of repair, immediate or delayed. Even in these circumstances, however, some free graft is usually required for the secondary defect, whether nearby or in a remote area.

Free Skin Grafts.—Any of the arbitrary thicknesses of free skin graft up to and including the whole skin depend for their continued survival on three cardinal factors. First, a recipient surface from which it can derive nutrition and quickly become revascularised during a lag period before cell death. All tissues normally satisfy this requirement except bare bone, bare tendon, bare cartilage or joint capsule. Secondly, the graft must be maintained in direct

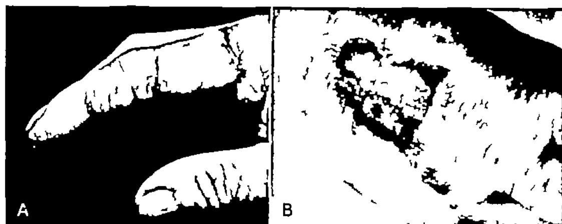


FIG. 56

Primary free grafts for traumatic wounds

Two cases where split-skin grafts have been applied in the primary treatment of recent traumatic injuries with skin loss. A, on the finger after a circular saw injury. B, on the back of the hand after a transport accident. Both pictures were taken at the first dressing five days after injury. In the case of (B) the overlapping graft margins have not yet been trimmed. One hundred per cent. primary healing is the object whether or not there is skin loss. Split-skin grafts should be freely used at primary operation in such cases.

and undisturbed contact with the recipient area for a time, which increases with the thickness of dermis in the graft. Thirdly, the graft must be autogenous.

Provided these three needs are satisfied there is no "chance" element in the take of skin grafts, as is often suggested. Failure of skin grafting is due only to misjudgment or errors of application and technique. Anything which separates a graft from its bed, such as pus, blood, inadequate or disturbed pressure fixation, will cause failure, not perchance but for a definite reason.

Split-skin grafts of half or two-thirds skin thickness are the most satisfactory for routine use on the hand (Fig. 56). They are usually cut from the upper thigh, the arm or the abdomen according to the amount and thickness required. The usual small areas needed can, with moderate practice, be easily and evenly cut by the free hand method, using a Blair or Humby knife. In many such cases only local anæsthesia is required. Larger areas, as for the whole back of the hand, are more easily cut as an even one piece graft with a dermatome.

Grafts of approximately half skin thickness carry a good bulk of the dermal layers They compromise between the advantages of a thinner graft which takes more quickly and easily and those of a whole-skin graft which has minimal subsequent contracture better ultimate texture mobility and sensory function

Thinner split skin grafts are only indicated as temporary skin dressings when either their subsequent replacement or a more proximal amputation is envisaged Under these circumstances, contracture and wrinkling in the graft do not matter The Thiersch or epidermal graft, in its true meaning, is never indicated [1]

Whole-skin grafts [2] (Wolfe or dissected grafts) offer the best functional result in hand defects especially on the palmar aspect, but they have a very limited application in practice The extra thickness of dermis renders their take and subsequent existence more precarious An even soft tissue base, meticulous hæmostasis and absence of infection must be guaranteed and the period of pressure fixation must be maintained for seven to ten days. Whenever skin is avulsed from the hand the fat is generally removed as well so that these conditions do not often occur When they do, however we believe that whole-skin grafts are warranted on the palm and volar aspects of fingers by the improved results which ensue. Smaller Wolfe grafts vascularise more quickly and more easily than larger ones, as also do those taken from donor sites where the skin is thinner The donor site of a whole skin graft presents its own problem of closure.

Whole-skin grafts may have occasional application in cases with extensive skin avulsion if the skin has not been damaged If local conditions are favourable, the skin of these flaps can be replaced and treated as a free whole skin graft, provided the fat is all carefully removed from it Such flaps, if sutured *in toto*, would certainly slough but the skin of the flap if undamaged is potentially viable and may be used as a free graft There is no problem of donor site In practice, however, this method is rarely used, as the type of injury in which it may appear to be useful is usually associated with direct damage to the skin itself of a degree which would make its survival as a free graft unlikely

Attached Flaps—When conditions are unsuited for free grafts or when the special advantages of a flap are required this can in some cases be obtained locally by lateral advancement or by transposition from a nearby area of the hand (Fig. 50) Local flaps can only be used for small defects, and only if they do not make secondary defects in important areas A flap from the side to the front of a finger or from the side of one finger to the front of its neighbour might be advantageous, but for the front of one finger to be attached to another would be folly For this and other reasons we do not favour the common practice of using palmar skin as direct flaps to finger tips

For all areas of size or when local flaps would create unacceptable secondary

[1] The term "Thiersch graft" is generally misused to denote any razor-cut graft. Most of these include varying thicknesses of the dermis and are therefore dermo-epidermal in type and not the tissue-paper thin epidermal or true Thiersch graft

[2] The terms "whole-skin graft" or "full-thickness graft" are frequently misapplied to denote flaps of skin and subcutaneous tissue. They mean the skin only—the whole skin and nothing but the skin.

defects direct flaps must be obtained from other areas (Fig. 57) Many potential donor sites have their advantages, but in the choice for any particular case the fullest consideration must be given to the economy of the procedure, the posture and comfort of a patient, the thickness and bulk of tissue required The flap must be carefully designed relative to its shape and margins, so that the whole defect is covered at the primary attachment. Raw areas must be kept to a minimum by careful grafting of all donor sites. There should be a minimum of open flap between its attachment and base

Small flaps are generally more difficult to design and manage than large ones For large flaps the indications are usually inescapable, but for small flaps we reiterate the need for careful discrimination in their use Further details of these procedures follow in Chapter VII

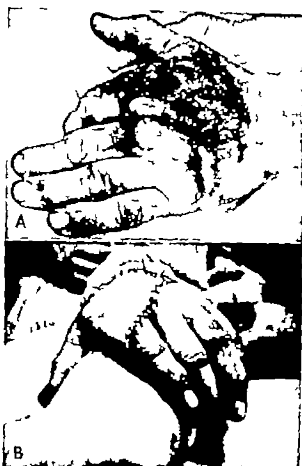


FIG. 57

Primary direct flap for a traumatic wound

A, Recent wound with extensive tendon damage and skin loss, the result of a power saw injury Despite a superficial resemblance to the case illustrated in Fig. 50 (A) it is obvious that the shape of this defect and its relative extent would not permit the design of a local flap of adequate dimensions. A primary direct flap must therefore be obtained from elsewhere.

B, Shows a direct flap from the opposite arm *in situ* Note the position of the thumb and fingers with the finger joints in a flexed posture.

CLOSURE OF TRAUMATIC AMPUTATIONS

The principles and methods already considered have equal force under this heading, for amputations are but a variety of open wound. Though no new principles are raised, the frequent presentation of these wounds warrants their general consideration as an entity

In the primary management of traumatic amputations, no more tissue should be removed than is necessary to close a stump with viable flaps. Nevertheless, sufficient bone must be removed to ensure that the stump is closed without tension over the bone end to prevent flap necrosis and its consequences Arguments concerning the ideal sites of finger amputation can generally be ignored After a period of trial with the maximum finger length that can be retained at a primary operation the patient is usually the best judge of whether further amputation is required

Filleted soft tissue from an amputation stump or a useless finger may prove of inestimable value to secondary repair in neighbouring areas (Figs 58 and 59)





FIG. 58

An opportunity which exists only at a primary operation

A, In this case excess of soft tissue from the middle finger is used as a direct flap to another finger

B End result of primary healing with conservation in length of the thumb stump



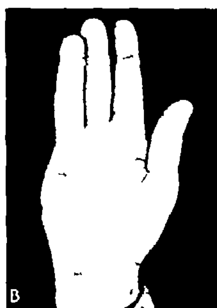


FIG 59

Use of a filleted flap in primary amputation

A, Illustrates how a filleted flap from an amputated index finger was used to repair skin loss at the base of a neighbouring finger and so preclude scar disability

B A similar type of flap from an amputated little finger has been used to prevent scar contracture from skin loss in the palm at the base of the ring finger

It may alleviate the necessity for lengthy staged operations and awkward positions for the patient. Every time we think we are "cutting losses," a phrase often used, by amputating what must obviously become a paralysed anæsthetic or

stiff digit, we may also be cutting off some heaven sent material for future surgical repair

Nor is it always right to shorten still further all open amputation stumps or finger tip areas of skin loss to effect closure If the thumb or index finger is involved or if there are other partial finger amputations on the same hand repulping should be considered as a primary measure in selected cases.

By providing adequate bone cover by either method, terminal osteitis is prevented So too is many an adherent tender scar about a finger tip which calls for treatment at a secondary operation. Nevertheless, many repulping operations have rightly been criticised as over-enthusiasm for restorative procedures. A carpenter with a shortened finger who can return to his work is better off than one with a vulnerable flap which prevents him doing his job without unreasonable details of care and constant awareness of his defect. *Management must be planned in relation to practical value and not surgical fantasies.*

In severe injuries the possibilities of ultimate reconstruction must always be envisaged at the primary operation so that the best foundations are made for that end. Repair mindedness can be cultivated—ability to visualise the optimum end result and how to achieve it.

CHAPTER VII

TIDY HAND WOUNDS AND THEIR COMMON SUB-TYPES

THIS group includes all the injuries produced by sharp-cutting edges It ranges from simple small and uncomplicated skin cuts to deep and extensive gashes which may be complicated by severed tendons nerves and major vessels

In the household knives, tin edges, broken glass, bread-cutters and all sorts of kitchen implements make such injuries commonplace. The problems of children who play with broken bottles or trip and fall with a glass in the hand or when putting out the milk bottles for mother are tragically common

In industry guillotines planing machines chisels, slaughtermen s knives and the like are all responsible for similar types of injury

These injuries have already been discussed in a general way (p. 63) Three special features, however, raise particular technical problems They are (1) skin and soft tissue loss (2) guillotine types of finger amputation (3) severed nerves and tendons

More than one of these features may be present in the same case but they will be discussed in relation to particular injuries

THE SIMPLE UNCOMPLICATED SKIN CUT

The majority of minor skin cuts require no more than careful cleansing and adequate cover until healed. They cause trouble only when these simple family remedies are neglected and sepsis results The enormous saving in absenteeism by the setting up of efficient first aid stations in factories bears striking testimony to the value of careful treatment of common lesions however trivial

The deeper or more extensive cut, still uncomplicated by damage to essential structures is often the cause of indecision on the part of the first-aid attendant and even the doctor as to whether it should be sutured or simply dressed and left to heal There is, however no doubt that the wound that is subjected to careful surgical cleansing accurate edge to-edge suturing and adequate immobilisation will heal soonest and with the least scarring. If combined with this practice, a routine injection of anti tetanic serum and of procaine penicillin is added sepsis will be kept at bay and the optimum result achieved in the shortest time. There must be few surgeons who would not expect such treatment if they accidentally cut their own hands, and, after all that is the ultimate criterion by which any method of surgery should be judged

SLICING INJURIES WITH SOFT TISSUE LOSS

Tissue loss is not only a problem of untidy injuries, for it may present as a localised defect of a most precise and clean-cut nature

Glancing or tangential injuries with knife blades or glass or from gouging, planing, chopping or slicing machinery may produce clean-cut areas of skin and soft tissue loss uncomplicated by damage to other structures. The resulting oblique and slice-off defects generally involve either a finger pulp, the exposed side of an index finger, thumb or little finger, the thenar or hypothenar regions.







FIG. 60

Slicing injury with tissue loss—treated by free grafts and local flap

A, The injury. The flexor profundus was exposed in the proximal portion of the ring finger wound.

B, First dressing, after split-skin grafts to index, middle and little fingers and the flap advancement with split skin graft supplement to the ring finger. The flap on the ring finger was needed to cover the area of exposed tendon. C, The end result one year later.

For any defect of significant size relative to the region the object of treatment is primary skin replacement. In practice *this is achieved by one of two* means.

Free Grafts of split skin achieve satisfactory and quick healing if the exposed wound surface is a suitable base for a free graft—*i e.* if there is no exposed bone, joint, tendon or nerve (Fig. 60). These features are often obscured by adherent hæmatoma. After cleansing and trimming the tissue defect, hæmostasis must be assured. *The graft should be cut* moderately thick—half to three-quarter skin thickness. *On* finger areas it is not usually necessary to anchor the graft with sutures, but the pressure dressing must be applied with great care to prevent shearing off of the graft when a round and round bandage is applied. The bulk of the dressing should be kept to a minimum on the fingers, but full immobilisation *is* essential.

The practice of relying on *a pressure dressing* to achieve ultimate hæmostasis for gross bleeding is not to be recommended. The pressure required is generally too tight for a finger and more than enough to

occlude at least the veins This not only prejudices viability but contributes to the vicious circle of painful swelling and further vascular occlusion. More over a blood-clot film soon becomes adherent beneath the graft and cannot be expressed merely by application of pressure.

Flaps of Skin and Fat are necessary if essential structures are exposed for repulping of the more important finger tip areas or if any deep structural repair in the region is indicated later The same object can be achieved by a number of methods each of which has its particular advantages and limitations.

LOCAL FLAPS generally designed on the lateral advancement principle (p 86) using a free graft on the secondary defect have a useful but limited indication for small areas of tissue loss in important regions The safe use of a local flap requires liberal dimensions It must be ensured that these can be satisfied without inducing significant secondary disability Flaps are more effectively advanced in the circumference of a finger than in a longitudinal direction (Fig. 60)

DIRECT FLAPS transferred as a two-stage operation from remote areas are more generally indicated Many donor sites are available but the following are of most value in practice.

1 *Cross finger Flaps*—For a localised defect on the front of a finger unsuitable for a free graft, an effective flap can often be designed from the side and back of a neighbouring finger Such a flap must be carefully raised so that it neither exposes important structures on the donor finger nor includes the more important areas of function or sensation A free skin graft is again used on the secondary defect. As the flap should be raised only from the side or back of the donor finger its application generally is restricted to the replacement of anterior defects on a finger When carefully executed for its true indication a cross-finger flap is most useful (Figs 61 and 62)

2 *Cross-arm Flaps* offer certain advantages to many cases The dorsal skin is of suitable texture and there is the right degree of subcutaneous fatty tissue for finger and hand cover Fixation is easily maintained while permitting of some mobility and variation in posture of elbow and shoulder joints The flap is best sited and designed with the palm of the recipient hand lying around the donor forearm so that its metacarpal and interphalangeal joints are slightly flexed (Fig. 57) This position is comfortable The only embarrassment for the patient is in regard to toilet and this can be readily overcome by understanding nursing. Forearm flaps are of special value for the dorsal surfaces of fingers, as these regions cannot be dealt with by the cross-finger flap method There is obviously a limit to the size of such flaps It is unwise to use the soft tissues which overlie the subcutaneous surface of the ulna

3 *Chest Flaps*—Direct flaps from the pectoral region are of satisfactory texture and thickness, and fixation of posture is easily maintained However we rarely use these flaps because they involve too much fixation and gross flexion of elbow and shoulder joints, and because we consider other areas are more suitable It is an inopportune donor site in women

4 *Abdominal Flaps* have special indications either for large areas or where multiple flaps are required or if thicker flaps are needed (Fig. 63) Although fixation and maintenance of posture are more difficult if the ipselateral side

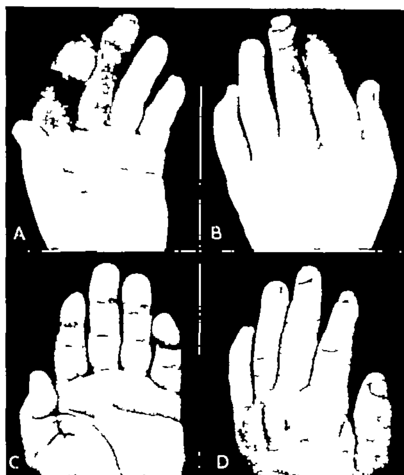


FIG. 61

Slicing injury with tissue loss treated by cross-finger flap

A, B, Dorsal flap from the middle finger attached to the margins of the pulp defect on the index. Split-skin graft to donor site.

C, D End result. Sensory examination of the grafted area two years after transfer showed as follows —

Light touch—von Frey 35 detected easily More sensitive on the flap (softer skin) than on the pulp of other fingers, but the same on the flap as on the area of original pad which remains.

Pin-prick—hyperalgesia and tingling. A prick is painful even at lightest measures.

Two-point discrimination—on other finger pads, 2 to 3 mm. on the grafted area, 5 mm. on the back of finger *i.e.*, region of donor site 7 to 10 mm.

Temperature appreciation within normal limits—easily detects 2° C. change in a cool room.

of the abdomen is used these disadvantages are outweighed by the mobility allowed in the larger joints With careful design of the flap in a position of natural ease we have relied on bandage and Elastoplast restraint bed posture

and pillow arrangements to maintain position. We rarely use plaster Immobilisation of the actual site is important during the early phases of the



FIG. 62

Slicing Injury with tissue loss—treated by cross-finger flap

A, The injury showing exposure of flexor tendons.

B, Shows the defect covered primarily by a direct flap from the dorsum of the index finger The secondary defect was covered by a thick split-skin graft.

C, D Three weeks later just prior to flap detachment. E, F The end result

attachment but some mobility is encouraged in remote joints Pressure sores are avoided entirely if plaster is not used Such is the early cerebral fixation"

of a posture that more active nursing efforts are often required to achieve movement or change in posture than to maintain a fixed position.

The basic design of direct flaps must be thoroughly appreciated.[1] A fabric pattern is needed for this purpose, working in reverse from the desired result through a stage of mimic attachment to the donor site. Only in this way are absurd mistakes prevented The complete area required for the defect should be attached at the initial operation so that no further area of flap is applied at the second or detachment stage. The smaller the flap the more careful and accurate must be its design and orientation. Indeed precision in dealing with a small area is more difficult than with a large area. *Rarely can a direct flap be detached* with safety in less than three weeks A delay operation is indicated if for any reason, more flap area is required than that initially attached

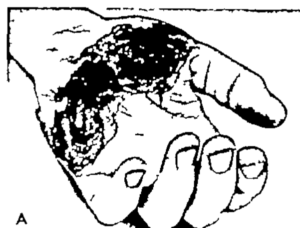




FIG. 63

Slicing injury with tissue loss—treated by abdominal flap

A, The injury caused by a planing machine, in which hypothenar muscles, terminal branches of ulnar nerve, transverse carpal ligament and thenar muscles were all exposed.

B The defect covered primarily by a direct abdominal flap.

Direct flaps are incompatible with out patient management, at least during the early days of attachment It must thus be realised that such operations should never be undertaken *light heartedly* The commitments of time and tedium for the patient and of detailed design and technique for the surgeon must be fully appreciated if the many hazards of the procedures are to be offset. Carefree use of such operations is conducive to failure and to the addition of further insult to an injury which already exists

GUILLOTINE AMPUTATIONS

Single or multiple guillotine finger amputations usually result from chopping accidents or cutting machinery The jagged saw wound does not come into this category Open bone section is the feature of the lesion and primary closure of the wound is essential, except perhaps in small children when these injuries heal quickly if kept clean by simple dressing routine.

[1] Gillies, H D (1932) The design of direct pedicle flaps. *Brit med J* 2, 1008.

As the open end of the digit is virtually a wound with tissue loss, closure can only be achieved either by further bone resection and suture of the local available soft tissues or by soft tissue supplied from another area In addition



FIG 64

An oblique guillotine amputation—treated by local flap and split-skin graft

A, The injury in which the exposed middle phalanx can be seen.

B, At the first dressing. The exposed bone has been covered by the volar pulp flap and the rest of the defect covered by a split skin graft. Note that this represents the shortest useful length of an index finger Further bone resection to allow the volar flap to cover the whole of the defect would have left a stump too short to be of any value.

to what has already been set out on page 94 concerning traumatic amputations the following generalisations can be applied to these injuries

There are many superficial slicing injuries to the sides and ends of the finger tips which do not involve exposure of bone These wounds can be covered effectively by split skin grafts provided there is sufficient subcutaneous tissue remaining to protect the deeper structures. How effective this remains will depend on its exact position in relation to finger tip apposition areas. The guillotine amputation stump however with its adherent hæmatoma over the area of bone section, is often wrongly regarded as a suitable base for a free graft. The graft generally fails to survive over the bone end which is thus left exposed and prone to sequèstration and adherent painful scar (Fig. 65)



FIG. 65

The bone end is left exposed and prone to sequestration and adherent painful scar

The treatment of election for most cases is to resect further sufficient bone

of a posture that more active nursing efforts are often required to achieve movement or change in posture than to maintain a fixed position.

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FIG. 63

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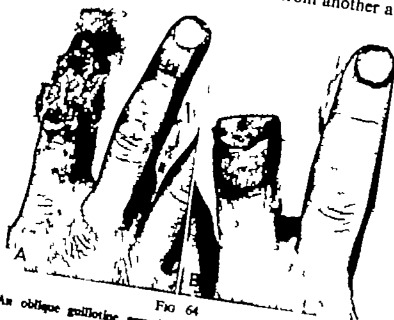


Fig 64

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B, At the first dressing. The exposed bone has been covered by the volar pulp flap and the rest of the defect covered by a split-skin graft. Note that this represents the shortest useful length of an index finger. Further bone resection to allow the volar flap to cover the whole of the defect would have left a stump too short to be of any value.

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Fig. 65

The bone end is left exposed and prone to sequestration and adherent painful scar

The treatment of election for most cases is to resect further sufficient bone



FIG 66

Guillotine amputation of index finger tip treated by cross finger flap

It should be noted that the *donor site for the flap is on the back of the middle finger and not the side.*



FIG. 67

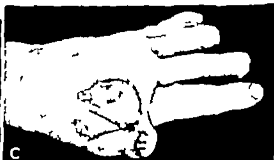
Guillotine amputations of finger tips—treated by direct closure after bone shortening and by local flap in the case of the thumb

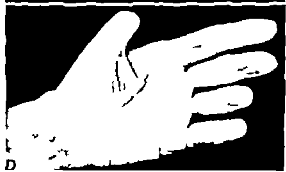
A, The injury in a rubber worker was caused by a wire burr

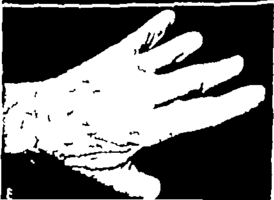
B, C Direct closure of middle, ring and little finger stumps after minimal bone shortening. Preservation of maximum thumb length by covering the end with a flap from the web space between thumb and index. The secondary defect was covered by a flap transposed into the thumb web from the dorsum of the hand The tertiary defect was then covered by a thick split-skin graft.

D E, The end result.









to enable the fashioning of soft tissue flaps and so permit of accurate closure without tension. Hæmatoma is the chief cause of secondary breakdown Throbbing pain is its tell tale symptom With present-day use of plastic techniques in casualty departments there is a common tendency to forget that this simple procedure is the treatment of choice in most cases.

Where the thumb or index finger is involved retention of all possible length is important The same may apply if more than one finger has been damaged In such circumstances repulping of the defect with a direct flap offers special advantages and merits consideration In the past direct flaps from the abdomen the chest and the opposite forearm have often been used for this purpose However experience has shown that abdominal and chest flaps which are tedious to design and fix make poor substitutes for finger pulps The skin texture is wrong, the flaps are usually too bulky and they develop poor sensory function Though forearm flaps are still used for multiple fingers or for larger areas of tissue loss, we have come to prefer cross-finger flaps whenever they can be designed with safety By using distally based flaps from the dorsum of a donor finger and carefully adjusting the degree of finger flexion a safe flap can be designed for each finger tip area (Figs 66 and 67)

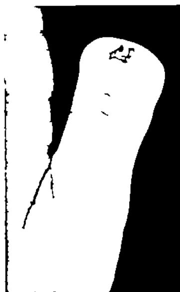


FIG 68
Rudiments of nail are an unsightly nuisance. The nail bed should be removed in proximal amputation through the distal phalanx.

We are averse to the use of direct palmar flaps in repulping amputated finger ends This involves the spoiling of a most important area of the palm and the fixation of a finger in such a degree of flexion for such a period that the recovery of full extension may be unduly prolonged or even incomplete Moreover the flaps do not lie as nicely as those that can be designed from other regions Despite the successes which have been claimed for the method its hazards do not warrant general application

Before applying direct flaps to distal finger stumps, small residual remnants of nail bed should be removed If left their subsequent irregular growth on the surface or under flaps may mar an otherwise satisfactory result (Fig. 68)

INCISED WOUNDS INVOLVING SEVERED TENDONS AND/OR NERVES

The most important structures damaged in tidy wounds of the hand are the tendons and nerves separately or in various combinations. We consider these together because in practice they are generally associated In passing to a detailed consideration of their primary management it must be recognised that in this chapter we are concerned only with the clean-cut incised wound seen within a few hours of the injury

There are many variations in tendon and nerve injuries, but one very important principle, common to all can be laid down—that, **with one important exception, primary repair of the divided structures, whether tendon or nerve or both, is indicated in all cases where the patient's general condition would not be prejudiced by such a procedure** The one exception which we concede is *where the long flexor tendons* are divided at any point between the metacarpo-phalangeal joint and the proximal interphalangeal joint The reason for this exception will become apparent later

Some have advocated delayed repair for all these structures for a variety of reasons Perhaps the earliest and most powerful of these was fear of sepsis, and there is no doubt that until a few years ago this was sound and reasonable argument But since the advent of antibiotics this fear of sepsis is a thing of the past, provided that all ordinary surgical principles are respected We have had no case of primary tendon or nerve repair which has failed because of *sepsis in the last twelve years*

Others have claimed superior results from delayed repair in the case of nerve injuries, largely on the basis that proximal and distal damage and reaction along the nerve cannot be accurately assessed at the primary operation, and that thickening of the perineurium during the waiting period makes the technique of repair simpler [1]

Most clean incised wounds have been inflicted by knives, fragments of glass, razor blades and similar agents in a single rapid action We have little reason to believe that in such cases the amount of damage to the nerve is appreciably greater than that which may be inflicted a second time some weeks later by the surgeon when he exposes, isolates and again sections the nerve in the process of a delayed repair Other largely hypothetical considerations have been raised to support the thesis of delayed nerve repair One emphasises the value of suture after a sufficient time has elasped for axonal degeneration in the distal segment This work, however is largely speculative and has not received general confirmation Indeed it appears to us that the only valid argument that can be raised in favour of delayed nerve repair in tidy wounds is that of expediency *We would be in entire agreement that* if at the time and place where the injury occurs there are not the requisite facilities and personnel available to deal adequately with the problem, it would be far better to decide upon delayed repair than to enforce the principle of primary repair at all costs. But this can hardly be introduced as a legitimate argument when considering truly surgical indications nor has it any force under modern civil conditions of specialist surgical centres and rapid transport War-time conditions of course, may *call for a different attitude*

In the five years that have elapsed since this book was published our continued experience of the primary repair of nerve injuries in tidy wounds has served only to strengthen our conviction of the essential correctness of this procedure It behoves any surgeon who advocates a delay of several weeks before repairing important structures such as major peripheral nerves not only to demonstrate that they can be so treated with good results, but also to show

[1] Nicholson, O R & Seddon, H J (1957) Nerve repair in civil practice *Brit med J* 2 1055

clearly that the results are sufficiently superior to those of primary repair to justify the social and other consequences attendant upon the delay and the duplication of surgical procedure. This is something that Seddon,[1] who has for many years been a strong advocate of secondary nerve repair, appears never to have done. The only cases of primary repair that he has mentioned as providing material for comparison are cases seen in his unit after primary treatment elsewhere Such comparisons are worthless Equally worthless are the inferences drawn from any recorded series of cases which takes no account of the ages of the patients treated The extraordinary differences in speed and quality of recovery between young children and middle aged or elderly patients simply cannot be ignored—the age of the patient is of the most profound prognostic significance We believe that no surgeon who has had the opportunity of bringing a high order of technical skill and experience to bear upon the primary repair of one or more major peripheral nerves in a child of say 4 or 5 years of age and who has seen the extraordinary speed and high quality of regeneration during the following three months would willingly abandon this in favour of a tedious secondary exploration and repair often at the point of division of the nerve into branches and often at a time when maximum mobility is required for the recovery of associated tendon injuries All that Seddon and his colleagues have demonstrated is that in a specialist unit where a high order of technical skill and experience are concentrated the secondary repair of peripheral nerves can give good results We believe, however that they would obtain the same or better results more simply and with far less time and trouble to the patient if they were to bring the same order of skill and experience to bear at the time of the injury

In accepting the general principle of primary repair we can now discuss the particular problems which the tendon and nerve injuries present in different situations.

TENDON AND NERVE INJURIES ON THE PALMAR SURFACE OF THE HAND

In the Fingers—This area is regarded as extending from the metacarpo-phalangeal joint to the finger tip and includes the distal portion of the palm as far proximal as the commencement of the digital theca. Occasionally tendons or nerves alone may be damaged in small puncture wounds, but the typical injury in this region involves one or both tendons and more often than not, one or both volar digital nerves

In this situation the tendon damage overrides the nerve injury in importance, particularly when only one nerve is cut Nevertheless the nerves must be respected and dealt with on their merits There can be no excuse for overlooking them for an anæsthetic finger is no small handicap Spontaneous nerve regeneration is common enough in the distal half of the finger but when the main nerve trunks are divided near the base of the finger it rarely occurs—particularly when the ends are further separated by the exposure and manipulations required in dealing with the tendons. The digital nerves are

[1] Seddon, H J (1949) *Proc roy Soc Med.* 42, 427

structures of appreciable size and irrespective of what is done to the tendons they should be repaired primarily in all cases.

Divided tendons in this area have always presented one of the difficult problems in reparative surgery Despite the fact that it is over forty years since Sterling Bunnell[1] first laid down the fundamental principles involved regular success in their management has come only to very few and to them only after years of trial and error

Whenever a tendon is divided no method of repair however meticulous and accurate, can prevent some adhesion between the tendon at the point of suture and the surrounding tissues Such is the nature of the healing process. The best we can ever do is to reduce this adhesion to a thin line of scar by *finesse in operative technique*.

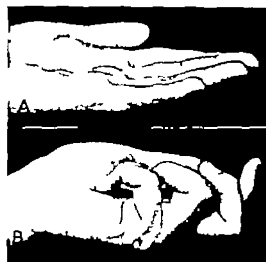


Fig 69
Primary flexor tendon repair in the little finger in a child of 13 years
Both tendons were severed over the proximal phalanx. Only the flexor profundus was repaired.

In other situations where tendons are surrounded by mobile paratenon and loose areolar tissue an adequate degree of tendon excursion can be achieved by stretching this surrounding tissue although the adhesion remains and there is no potential space between visceral and parietal synovial layers

In the finger the tendon is enclosed within a relatively rigid sheath which has no such elasticity in the direction of pull of the tendon The inevitable adhesion at the point of tendon suture must therefore fix the tendon absolutely *It is this fact which has accounted for* the almost uniform failure of simple *direct tendon suture in this region* Two procedures have been employed to overcome this problem

1 The first is to excise widely the tendon sheath except for a small portion well away from the point of suture, which is left to prevent prolapse of the repaired tendon The adhesion at the site of tendon repair is now to the subcutaneous tissue and through it to the skin If the amount of scar is minimised tendon function can be obtained and in some hands good results have been produced by this means (Fig. 69) In small children this is all that is required and good function is the rule for they appear to retain some power of remodelling structures over and above the ordinary methods of tissue repair Nevertheless the amount of subcutaneous tissue is not very great in the fingers and the flexor skin is *relatively rigid* Moreover posteriorly there is only bone or joint capsule and if as is not uncommon the cut extends through the *posterior synovial layers*, little can be done to obviate the effects of adhesion here For these reasons

[1] Bunnell S. (1918). Repair of tendons in the fingers and description of two new instruments. *Surg Gynec Obstet* 26, 103.

direct tendon repair even after excision of the theca still fails frequently in most surgeons hands and the second method is advocated

2 This method aims at transferring the point of tendon suture to another ituation where the surrounding tissues are more elastic or where adhesions are f less import To achieve this the entire tendon is removed from a point well proximal in the palm to another beyond the distal interphalangeal joint. This segment is replaced by a free tendon graft carrying its own surrounding paratenon

A modification of this method is sometimes applicable in the case of the thumb It involves sacrificing only the distal segment of the cut tendon and then sliding the tendon origin down the muscle belly in the forearm This gives an additional length and allows the tendon to be sutured close to its insertion into the distal phalanx

These procedures, involving an extensive dissection and the use of free grafts whose viability must be carefully guarded constitute the one exception conceded to the rule of primary repair in the tidy wound In these circumstances a careful primary skin closure is carried out (Fig. 70) but the tendon graft is left for a secondary procedure of election under the most favourable conditions, as discussed in Part Four of this book Nevertheless this relegation to the group of delayed or secondary procedures depends largely on the two factors of fear of sepsis and surgical expediency which have already been overridden in establishing the principle of primary repair It seems, therefore, that there is no real reason why under the best conditions of modern surgery they too should not ultimately take their place as a primary method of treatment

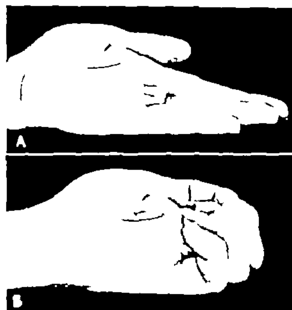


Fig. 70
Primary treatment of open tendon injury in the finger
The skin wound has been carefully sutured but no attempt has been made to repair the tendon at this stage

In the case of the thumb with its single tendon management does not vary according to the point of section on the thumb In the fingers however circumstances are different at different levels, for either or both of the two flexor tendons may be cut. When both tendons are cut primary treatment consists simply of meticulous skin closure Secondary tendon graft as a later procedure of election in these cases is considered in Chapter XIII

Where the profundus alone is cut the decision is often a difficult one, depending on the exact point of section. If this is so far distal that its suture cannot embarrass an intact sublimis tendon in its action on the first interphalangeal joint, then primary repair is indicated (Figs 71 and 72) This opportunity is often missed under the misapprehension that all flexor tendons cut in the finger should be left for secondary graft—a generalisation which applies only to a region as far distal as the insertion of the flexor digitorum sublimus In fact, if primary repair is not carried out at this stage, subsequent tendon retraction through the sublimus tunnel which closes behind it may

make it quite impossible to repair the tendon directly as a secondary procedure even within a few weeks, and the only opportunity of restoring the end joint function without prejudice to the proximal joint is lost The tendon, however is often cut in the region of the first interphalangeal joint or even as far proximally as the commencing bifurcation of the sublimis tendon *Its repair* at this point could interfere with an intact sublimis, and here again simple skin closure is indicated primarily The indications for further surgery in these cases are considered in Chapter XIII It is a good rule in primary treatment



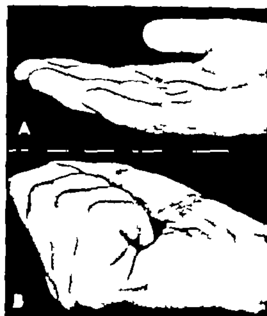


Fig. 71 Fig. 72

Primary repair of flexor digitorum profundus to all fingers

Fig. 71—Result after primary repair of flexor digitorum profundus of little finger—cut just short of its insertion.

Fig. 72—The profundus tendons to all fingers were divided beyond the proximal interphalangeal joints.

that the function of an intact sublimis tendon should never be sacrificed or jeopardised

In the Palm —This area extends from the distal end of the transverse carpal ligament where the tendons emerge from the carpal tunnel to the region of the metacarpo-phalangeal joints

Here the injury may be a localised puncture wound such as that inflicted by running a chisel into the palm when any or all of three structures related to a particular finger may be divided These are the flexor tendons, the common volar digital nerves arising from median and ulnar trunks and the lumbrical muscles It is noteworthy that in oblique penetrating wounds the point of damage to any of these structures may be remote from the site of the puncture

In other cases the injury is more extensive, as when a knife edge is drawn across the palm or a child falls with a glass or bottle in its hand Structures to more than one finger are *often involved*

The rule of primary repair stands for all these injuries. There are, however, two other important principles which influence treatment

Firstly a fully functioning flexor digitorum profundus, acting alone, will do all that is *normally* required in finger flexion The presence or absence of the flexor sublimis has very little effect on the everyday use of the hand. Secondly, if two tendons are repaired side by side within a limited space it is *impossible* to avoid some degree of cross union. When this occurs the two tendons move as one, and their combined effect is that of the tendon which is attached more proximally This means that the independent action of flexor profundus is lost For these reasons it has become sound practice to concentrate attention on the flexor profundus alone when both tendons are cut Only the profundus is repaired and the sublimis is resected so that there will be no fear of cross-union When the profundus alone is cut it is repaired when the sublimis alone is cut it is disregarded

The tendons lie deeply in the palm and are here surrounded by the loose synovium of the ulnar bursa so that rigid adhesions do not present the same problem as in the finger In this region too the profundus tendons give rise to the lumbrical muscles which can often be wrapped around the point of tendon suture as a further insulation to minimise the effects of adhesion Primary tendon repair therefore can be expected to achieve good results at this point, and there is no indication for any of the special procedures used in the fingers.

On the ulnar side of the hand injuries at this level do not usually involve the long flexor tendons but extend down through the hypothenar muscles to involve one or both of the terminal branches of the ulnar nerve The superficial portion of this nerve and its branches are easily identified and sutured but the motor branch which supplies most of the small muscles of the hand, passes deeply from its origin The isolation of its distal segment may involve a difficult and tedious dissection in the depths of the palm through the origin of the hypothenar muscles. Primary repair of this nerve is of particular importance for its exposure through scar as a secondary procedure is always difficult and may be well nigh impossible.

At the Wrist—The characteristic injury in this region is the suicide cut or the laceration suffered by falling with the outstretched hand through a glass window or door It may involve many or all of the long flexor tendons and one or both of the median and ulnar nerves

Here again the tendons are surrounded by loose synovium, and primary repair is indicated The tendons however, are closely grouped together and some cross union at suture points is inevitable This can be largely obviated by resecting the sublimis tendons in the region of the injury and concentrating on a careful repair of the flexor pollicis longus and the profundus group which is still incompletely subdivided at this level

The recognition and repair of these tendons is a simple matter at a primary operation but can be tedious and difficult through a mass of scar at a secondary procedure

It is our practice to repair also the nerves at the primary operation for

whatever the merits or demerits of delayed nerve repair it is essential that the tendons and nerves be repaired at the same operation Nothing could be more prejudicial to the results of a tendon repair than to carry out a second operation on the nerves in the region and reconstitute immobilisation in flexion at the very time when active mobilisation is necessary to restore finger movement and to prevent flexion contraction.

The primary operation in these cases becomes therefore, a long and tedious procedure involving several hours of painstaking surgery often at an inconvenient time for the surgeon, but it is the procedure of choice and the results can be among the most gratifying in hand surgery (Fig. 73)



FIG. 73

Primary repair of tendons and nerves at the wrist

All structures anterior to the wrist were severed by a glass cut. The median and ulnar nerves, the flexor pollicis longus and all tendons of the flexor digitorum profundus were repaired primarily The illustrations show the state of the hand eleven months after injury The patient had recovered sensation to the tips of all digits and motor recovery in relation to both nerves was still progressing.

TENDON INJURIES ON THE DORSUM OF THE HAND AND FINGERS

Injuries of extensor tendons have never been regarded by surgeons with the same apprehension as those of flexor tendons. Indeed one often hears experienced surgeons say that it does not matter much how you repair extensor tendons for they always do well

It may therefore surprise many when we say that in our opinion this generalisation is not borne out in practice and that some of the problems of extensor tendon repair are at least as difficult as those of flexor tendons, if not more so

The reason for this divergence of opinion is not ... d—it lies in the standards by which results are ... In the ... tendons the result has to produce an almost co... re it becomes worth while and before the ...

an embarrassment to the hand On the contrary nothing like the same degree of perfection is required of extensor tendon repair before the finger can play a useful part in hand function

Because of this one finds generally a very different standard of values in the two cases Results are assessed not so much on a basis of how the repaired extensor tendon functions in relation to normal as on how much it embarrasses the function of the hand as a whole in its everyday use While such a method of assessment is, no doubt, of considerable practical value it cannot be taken as an index of surgical accuracy and perfection

We consider that a true evaluation of results can only be made by careful comparison with the normal It is only with the normal as our standard that we are likely to make progress in this important field of surgery

There are a number of differences between flexor and extensor tendons which make for greater difficulty in the matter of successful repair

1 The extensor tendons are flat and in parts very thin. This makes the technique of suturing with accurate end to-end apposition and without fraying, overlap or " bunching up " of the tendon ends more difficult

2. On the dorsum of the hand and in particular on the fingers there is a relative lack of soft tissue cover which makes adhesion between the tendon and the surface difficult to overcome Extrusion of non-absorbable sutures is also more likely

3 Bones and joints are much closer to the dorsal surface, and concurrent injury to these structures is more common than on the flexor surface.

4 The distinction between the extensor tendon and the posterior capsule of the finger joints is lost and a divided tendon in these regions means a tendon repair over an open joint.

5 The subdivisions of the extensor tendons their attachments and their relation to the overall function of finger extension are far more intricate and more difficult to restore accurately than in the case of flexor tendons

The problems listed are real ones and their solution is in some cases still a long way off As on the flexor surface, the difficulties are greater on the finger than they are on the hand and wrist These difficulties are to some extent offset by the absence of any rigid sheath such as encloses the flexor tendons in the finger and by the fact that the degree of tendon excursion required to produce full extension is less than that in the case of the flexor tendons

Certain regional problems of extensor tendon repair can be set out as follows.

Distal to the Metacarpo-phalangeal Joint —Although the tendon expansion may be divided at any point in this region the typical injuries occur over the prominent joint regions when the fingers are in flexion Two separate problems arise in relation to each of the interphalangeal joints.

AT THE PROXIMAL INTERPHALANGEAL JOINT —Here the expansion is broad and consists of a central portion which is passing to an attachment at the base of the middle phalanx, and two lateral elements which spread round the sides of the joint and consist largely of the tendons of the short muscles as they take their part in the formation of the extensor tendon complex It is the central slip, lying taut over the back of the flexed joint which is so prone to injury

whatever the merits or demerits of delayed nerve repair it is essential that the tendons and nerves be repaired at the same operation. Nothing could be more prejudicial to the results of a tendon repair than to carry out a second operation on the nerves in the region and reconstitute immobilisation in flexion at the very time when active mobilisation is necessary to restore finger movement and to prevent flexion contraction

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The reason for this divergence of opinion is not difficult to find—it lies in the standards by which results are measured In the case of flexor tendons the result has to produce an almost complete range of finger flexion before it becomes worth while and before the finger fulfils its purpose and is no longer

an embarrassment to the hand On the contrary, nothing like the same degree of perfection is required of extensor tendon repair before the finger can play a useful part in hand function

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If the cut is a deep one and enters the joint, it may divide both central and lateral elements The resulting disability will then be immediate and apparent, for there will be no active extension at either of the interphalangeal joints. Much more commonly however the injury involves only the central portion or perhaps the central and one lateral slip In this case the tendon injury is by no means always apparent for the intact lateral elements, passing across the joint in a plane behind the axis of the finger are able temporarily to take over the function of extending this joint.

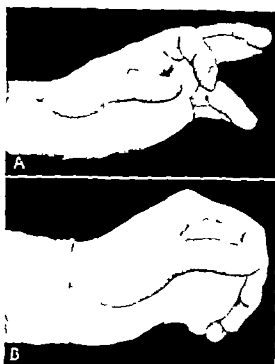


Fig 74

Position of immobilisation following repair of extensor tendons on the dorsum of the hand

A, A common mistake in immobilisation after repair of extensor tendons. A primary repair of extensor digitorum communis to the middle finger severed on the back of the hand has been carried out. The middle finger only has been immobilised. It is immobilised in extension, and the distal extension of the volar slab from the palm also immobilises the index, ring and little fingers with the metacarpo-interphalangeal joints extended

B, Correct position of immobilisation following such an injury

The bandages enclosing hand have been removed for clarity

It is commonplace for this injury to be overlooked in casualty depart ments, and for the patient to be sent home after simple skin suture with the assurance that no harm has been done In the succeeding days and weeks, however the ends of the central slip become separated, and the two lateral slips, as they are now free to slide around the sides of the joint become less and less efficient as extensors of that joint. Sooner or later they are displaced to such degree that they no longer pass dorsal to the axis of the finger and from then on no effort on their part can extend the proximal interphalangeal joint On the contrary they now act as additional flexors By this time a flexion defor mity of the proximal interphalangeal joint is well established

Two additional effects become apparent at this stage, viz. a hyper extension deformity of the distal interphalangeal joint and a loss of independent flexion at the distal interphalangeal joint in the initial stages of the co-ordinated " wind up of finger flexion Because of the excessive but futile action of the short muscles in trying to extend the proximal joint, their efforts produce a hyperextension of the end joint The condition is aggravated by the absence of the normal antagonistic extensor action on the proximal joint during finger flexion This action is diverted to the end joint and the profundus tendon cannot produce any independent flexion here until the proximal joint is almost fully flexed

The end result of all this is a gross flexion deformity at the proximal joint

with hyperextension of the end joint. While this may be passively corrected at first ultimately joint changes prevent a full range of passive extension of



FIG. 75
The characteristic deformity that results from division of the central slip of the extensor expansion over the proximal interphalangeal joint.

the finger, and a deformity is now established which is extremely difficult to correct (Fig. 75)

Awareness of the frequency of this injury and its early recognition are all important, for primary repair of the divided portion of the tendon offers the only chance of preventing progressive deformity (Fig. 76) Such a repair is not easy for the central slip is divided very close to its insertion and it becomes even more difficult if it has to be attempted at a later date when secondary changes are established

It is usually claimed that in this and in the similar injury occurring at the distal joint, tendon suture is unnecessary because the ends of the tendon can be maintained in apposition by splinting in extension for a sufficient period Results do not appear to bear this out, and it is our opinion that the best chance of functional recovery is offered by a careful surgical repair of the tendon followed by the necessary immobilisation and after-care

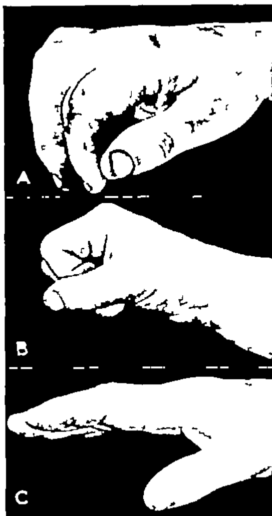


FIG. 76
Primary repair of central slip of extensor expansion

A, Clean glass cut over the proximal inter phalangeal joint Note the posture of the index finger which is flexed to a greater degree than normal in relation to the other fingers.

B, C, Result following primary repair of the central slip of the extensor tendon.

The secondary procedure to be adopted in cases with the established deformity or where primary repair has failed will be considered in Chapter XIII.

AT THE DISTAL INTERPHALANGEAL JOINT —Similar cutting injuries at this point which divide the extensor expansion produce the typical mallet finger deformity with inability to straighten the end joint If this is neglected

a secondary hyperextension of the proximal joint slowly develops from concentration of the extensor pull on the joint (Fig. 77)

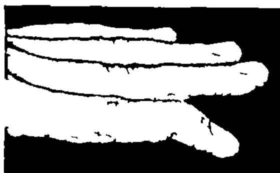


Fig. 77

Typical mallet finger deformity following severed extensor expansion over the distal interphalangeal joint. Note the hyperextension of the proximal interphalangeal joint.

This type of case, where the tendon is cleanly divided over the back of the joint, must not be confused with the subcutaneous tearing injury which produces the same deformity. The management and prognosis are very different in the two cases.

Here again primary repair of the divided tendon offers the best chance of restoring function (Fig. 79). This can be carried out much more easily at a primary operation than if relegated to the ranks of secondary procedures to be *adopted only if primary treatment* by splinting fails.

In children before fusion of the terminal phalangeal epiphysis a dorsal compound injury in the region of the terminal interphalangeal joint, such as may be received from a blow with an axe or from crushing the finger in a door

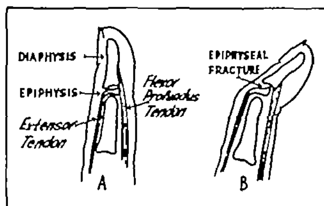


Fig. 78

The relation between the flexor and extensor tendon insertions into the distal phalanx

The flexor tendon inserts mainly into the diaphysis and the extensor tendon into the epiphysis, so that when the epiphyseal line is rendered unstable by fracture the pull of the tendons on the two fragments will produce a mallet finger deformity. *This resembles that resulting from a* severed extensor tendon, but the point of angulation is situated a little farther distally.

or from other similar injury may produce a mallet finger deformity which resembles closely that of the severed extensor tendon but which in fact is due to forward angulation of the diaphysis on the epiphysis. *This type of deformity* is due not only to the direction from which the blow is received but also to the differences in the manner of insertion of the flexor and extensor tendons into

the distal phalanx (Fig. 78) A lateral radiograph will assist in making the correct pre-operative diagnosis in these children in whom it may be very difficult clinically to distinguish between the two conditions

Over the Metacarpo-phalangeal Joint or Knuckle —This is a common site of injury and the metacarpo-phalangeal joint is usually laid open It is easily recognised by the posture of the hand and the inability to extend the

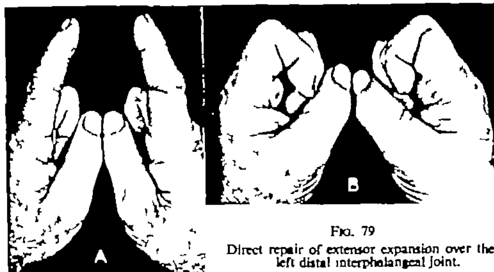


FIG. 79
Direct repair of extensor expansion over the left distal interphalangeal joint.

metacarpo-phalangeal joint against gravity If the hand is rested palm down on the table with the finger tips resting as if on the keyboard of a piano the affected finger cannot be lifted from the surface of the table and the effort produces only a weak extension of the interphalangeal joints and an increase in metacarpo-phalangeal flexion by the action of the short muscles Primary repair of the affected tendon is indicated It can be simply carried out and will give good results provided there is no associated intra-articular damage.

On the Dorsum of the Hand and Wrist —In this region the problems of tendon repair are simplest and primary repair of *all* the divided structures should be carried out Of particular importance is the principle of repair in layers It is a simple matter to mobilise some of the loose paratenon on the dorsum to surround and cover the suture point in the tendon and so obviate the effects of cross-tendon union and adhesion to the underlying bone or surface skin

Where the tendons are divided within the tunnels under the extensor retinaculum a sufficient amount of this structure should be removed to allow free movement of the repaired tendon A small portion is retained to prevent subsequent prolapse

SOME ASPECTS OF TECHNIQUE IN NERVE AND TENDON REPAIR

While the foregoing account of the principles and procedures to be adopted in the repair of nerves and tendons is regarded as being of the utmost

importance, its acceptance is only the first step towards success. It is of little use knowing what to do if the technical execution is at fault, for in this type of surgery probably more than most others, the results achieved are directly dependent upon the highest possible order of atraumatic technique.

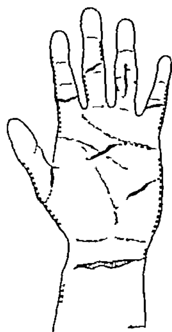


FIG. 80

Methods of extending existing wounds for exposure and primary repair of deep structures.

It is not only useless but entirely unjustifiable to approach these operations with the standard instruments, suture materials and operative methods which are employed universally in most general surgical procedures There is no more reason for such an approach than there would be in the case of a penetrating wound of the eye an inhaled foreign body or any other delicate or specialised surgical emergency

The first consideration therefore is the correct armamentarium for the job and a high order of skill and experience in its use.

Next in importance is the surgery of access to the damaged structure, and the following principles cannot be disregarded —

1 As in all surgery proper access is essential This usually means enlarging the existing wound. Much care and thought are needed in enlarging wounds or planning new incisions (Fig. 80)

2. No longitudinal incision on the finger should ever be placed farther forward than the lateral limits of the flexion creases (Fig. 81) The effect of scar contracture following a longitudinal incision farther forward than this is seen in Fig. 123

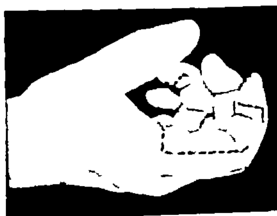


FIG. 81

A true lateral incision joins the extremes of the flexion creases when the finger is flexed. It is often made too far anteriorly

3 No incision should be continuous from palm into fingers or thumb However lateral incisions along the index finger and thumb or medial incisions along the little finger may be legitimately extended along the lateral or medial border of the hand.

4 Incisions or extensions of existing wounds in the palm should be transverse or oblique and not longitudinal

5 Tendons and nerves should be approached indirectly by raising skin flaps rather than by making direct incisions over them and along their length. The "Z" principle can be applied if the existing wound is longitudinal

The use of the tourniquet to ensure a bloodless field for working is obligatory in any operations on the tendons and nerves of the hand at least during the period of dissection

The needles, suture materials and method of insertion to ensure firm end to-end apposition are largely a matter of personal preference

For the main tendon suture we use a medium waxed silk or braided nylon (No 4/0) threaded at each end on No 3 atraumatic 3/8 curved cutting-edge needles They are threaded by our own staff using the special clamp provided Auxiliary apposition stitches are some times required so as not to leave any open tendon end exposed For these we use a finer stitch (No 5/0) threaded on a No 6 atraumatic curved cutting-edge needle The method of using the double threaded stitch is that described by Bunnell[1] (Fig. 82)

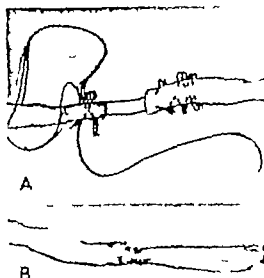


Fig 82

The Bunnell tendon stitch which we have used for all cases of flexor tendon repair

A, The stitch inserted.
B The stitch drawn tight and tied

The size and nature of these suture materials are directly related to the principles of post-operative care which we use and advocate. It is pointed out here that there is no tension or strain on suture points and therefore no necessity for the use of stronger and less workable materials such as wire. The theoretical and experimental evidence that silk causes more local reaction than wire is often quoted We have seen no evidence of this in practice. There are more important factors in technique, such as the amount of material used and the method of its use, which far outweigh any slight variation in local tissue reaction

For nerve suture we use finest waxed silk threaded on No 6 or even smaller atraumatic needles Only the perineurium is sutured The spacing of sutures is important. Posterior sutures are inserted first and it helps if most of the sutures are inserted before any are tied The nerve ends are not trimmed in sharp cut wounds but all adherent hæmatoma must be removed The importance of correct orientation is again emphasised and separate funicular suture is of advantage where practicable. This can often be done with the ulnar nerve at the wrist

AFTER TREATMENT OF REPAIRED TENDONS AND NERVES

The completion of an operation for tendon or nerve repair marks the beginning of a lengthy period of meticulous post-operative care subdivided into two stages —

1 The stage of complete immobilisation to promote early healing and consolidation of the divided structures.
2. The stage of graduated restoration of function under supervision

[1] Bunnell S. (1956) *Surgery of the Hand*, 3rd ed Philadelphia J B Lippincott.

It must be remembered that healing time varies from one tissue to another and indeed from one part of the body to another depending upon such factors as blood supply the degree of differentiation of the tissue concerned and the stresses to which it is normally subjected

Following on repair of major nerves it is our practice to maintain immobilisation for about two weeks and then to commence a gradual supervised return to active use within the limitations imposed by the nerve lesion

In the case of tendons it has been shown (Mason and Allen)[1] that subsidence of the early reaction after operation and the commencement of consolidation in tendon union are slow processes and it is not until the third week after operation that the point of union will take any strain without the risk of rupture. If this be so then it is apparent that any attempt at active movement before this time relies almost entirely on the suture material and its hold upon the tendon ends

It has therefore always been our practice to maintain absolute immobilisation until the third week and then to commence supervised active movements within the inner range *i.e* flexion from the position of immobilisation, once or twice a day still maintaining the fixation splint between these sessions until the fifth week At this stage consolidation is sufficiently established to withstand normal stress, and restraint can safely be discarded

This practice conforms with one of the main general principles we have tried to make throughout this book—that early primary healing and early return to function of the damaged hand are mutually incompatible, for healing implies rest and function implies the opposite **Healing must always precede function if both are to be achieved in the shortest possible time** Any attempt to reverse this order or to encourage both simultaneously usually results in delayed healing and incomplete or ineffective function

Thus, during this early post-operative period immobilisation must be absolute, and the splints and bandages must be repeatedly checked to ensure this One of the commonest causes of failure is inadequate splinting. Bandages must never be allowed to come loose nor plaster slabs to bend and break

At the end of the period of absolute immobilisation the splint is taken off the skin sutures are removed and active movements within a limited inner range begin under a trained physiotherapist. She must have a clear idea of her objective and know how much strain can be placed on the tendon at this and subsequent stages. Such knowledge only comes with experience, and a physiotherapist who is really good at her work is invaluable.

In the case of nerve injuries the further management includes detailed recording of sensory and motor loss splinting to relax affected muscles and prevent contraction in their antagonists

The later management of tendon injuries may also be prolonged but once on the right road to functional recovery the patient can usually be left to complete the process by his own efforts The end result is rarely achieved quickly but usually by slow steady improvement for at least six months and

[1] Mason, M L & Allen, H (1941). *Ann Surg* 113 474

often longer Occasionally in flexor tendon repairs restoration of full extension is slow in spite of progress in flexion In these cases an elastic traction extension splint as discussed below, can be used cautiously after about six weeks for a few hours a day

In extensor injuries the chief problem, after the initial immobilisation is not the recovery of active finger extension but the restoration of a full flexion range This should be the aim right from the start of active movements and it is here that a knowledge of just how much strain can be put on a repaired tendon at any given time is of the greatest importance Too often it is forgotten that **full flexion is more important than full extension,** and it is not until too late that the surgeon who has been directing all his efforts to restoring extensor function suddenly realises that the hand can never again be closed in full finger flexion

When tendons and major nerves are divided simultaneously at the wrist the after-care problem is particularly difficult. The chief difficulty is the absence of effective antagonists to the repaired long flexor tendons because of small muscle paralysis This, if uncontrolled invariably leads to gross flexion contracture of the affected fingers which will be fixed and intractable by the time nerve recovery eventually restores the antagonists

Such a state of affairs must be anticipated and a traction extension splint provided after about five or six weeks to substitute for the finger extensor mechanism Active flexion can then be continued against the elastic pull of these splints and tendon contracture overcome (Fig 83)

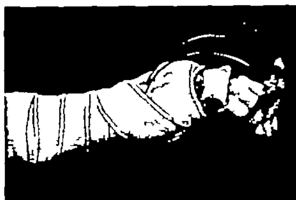


FIG. 83

Finger traction to restore full finger extension after combined tendon and nerve injuries on the front of the wrist. The splint substitutes for the small muscles in opposing the action of the long flexor tendons. Without such splints an intractable flexion contracture of the fingers is the rule in these cases.

Other postural changes associated with the many variations in combined nerve and tendon injuries can similarly be corrected by splints of non rigid elastic nature which permit of controlled function during the period required for nerve regeneration

The emphasis in this chapter on tendon injuries and the relatively scant reference to nerve repair and regeneration might be questioned

Unlike tendon injuries isolated nerve injuries in the hand present no particular regional problems and have been exhaustively covered in other works. Our main object has been rather to discuss their association with tendon injuries, which is how they generally occur We feel that it has been their dissociated consideration which has led to some divergence of opinion and teaching and perhaps some equivocal results. Hand surgery must not be fragmented into separate systems

CHAPTER VIII

UNTIDY WOUNDS AND THEIR COMMON SUB-TYPES

HERE, again the main technical problems of primary surgical treatment can be conveniently discussed in relation to certain common type injuries. Again we recognise the frequency of common ground between one type of injury and another and that various problems may present in any one injury

THE CRUSHED OR PULPED FINGER TIP

We are not concerned here with the simple compression injury of "jammed finger" but rather with those more severe mangling or crushing injuries to a finger tip as caused by machinery Of all the localised hand injuries there are none more difficult to treat with complete satisfaction to both patient and surgeon They are extremely painful injuries and detailed decisions are often not easy



FIG. 84
Crushed finger tips.

They usually involve soft tissue laceration or loss, compound fracture, open joint and gross damage to nail bed (Fig. 84) When bone exposure and soft tissue loss are both present it is usually best to resect sufficient bone to facilitate end closure by viable soft tissue This is not always necessary however and in some cases it may be possible, by rearrangement of the remaining viable skin to cover the bone end without further resection Sometimes it will be decided to repulp a finger tip by one of the procedures already described in order to preserve length in the more important fingers or the thumb This applies particularly to patients in certain specialised occupations The severity of the injury must be the chief deciding factor between these alternatives. There can be no justification for haphazard suturing of crushed flaps and skin tags of dubious viability nor has tension suturing any place In some finger tip injuries, such as those due to fine cogs there is no end to the complex ramifications of cuts or splits—indeed the wounds can often only be described as "chewed up Any attempt to suture these wounds may precipitate necrosis in otherwise viable areas. A few carefully placed fine sutures which do not include much more than the epidermis can be effective in some of these cases. In others a carefully applied firm dressing can hold the multiple small flaps together satisfactorily There is some place, therefore for conservation after cleansing, and then awaiting the declaration of time provided always that there is no bone exposed

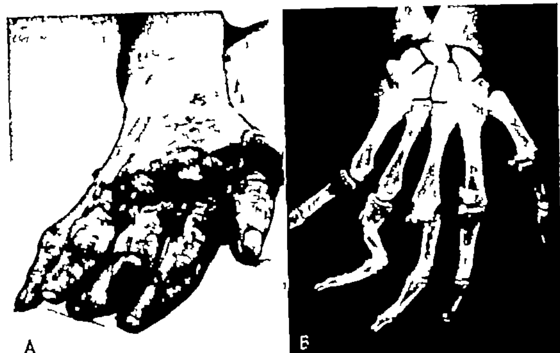


Fig. 85

A power-saw injury

The oblique line of damage and partial amputation are typical.

Fig. 86

A, B, Severe open injury of the hand following accident with a dough-mixing machine.

C D Three years after primary repair in one stage involving two weeks only in hospital. It seemed obvious that the only potential function of the hand was between the thumb remnant and the little finger so the index and middle metacarpals were widely reduced, the stumps closed with local flaps, and the residual raw area covered with thick *split skin*.

Illustrates the advantage of proceeding directly to the end result. Primary closure would otherwise have implied a direct flap, an extensive area of defective sensation, and function probably not as good.

MANGLED FINGERS

These injuries are typically caused by power-driven saws (Fig. 85) They contrast with guillotine type amputations already discussed.

Viability and Extent of Damage.—The decision is easy where fingers are left in continuity only by skin tags or tendons. If both neurovascular bundles are severed near the base of a finger it is unlikely that the distal segment is viable In any case bleeding should be demonstrated in any distal segment or skin-flap area if its retention is contemplated The extent of local damage must be carefully noted in relation to soft tissue loss tendon and nerve continuity and bone or joint injury

Conservation or Amputation.—*Conservation* can be considered only if the distal segment of finger is viable and only if there is likely *prospect of a useful*



FIG. 87

Indication for primary amputation

A severe compound injury of one finger of the left hand in an elderly subject. Open joint and fracture severed flexor tendons, skin and nerve loss all constitute positive indication for primary amputation. Reparative surgery is wasteful and bad treatment without reasonable prospect of a worth-while result.

digit resulting. This in turn must be related to the total extent of damage to the hand which *finger is under consideration* and which part of that finger In the case of a thumb there is every argument for conservation provided only that it is viable and the wound can be closed In other fingers arguments for conservation become successively weaker toward the little finger Where there is damage to flexor tendons as well as *nerves, and joint or bony injury* there *is less prospect of* a useful finger resulting and in many combined injuries of this sort there is no valid argument for conservation if the remainder of the hand is not grossly damaged Primary amputation *for a badly damaged*

single finger (Fig. 87) is often good treatment but the argument in favour of its retention becomes progressively stronger the more severe the damage to other fingers. Even a stiff finger if slightly flexed and short, may be a useful and essential component of a mutilated hand remnant. With multiple finger injuries, arguments concerning the optimum length of finger stump for useful function have little place at this stage of treatment. It is right to conserve all finger length which can be safely closed with viable tissues, no matter what the ultimate fate of any such stump might be at a secondary and more elective review

Control of Open Fractures —When the decision is against finger amputation open fractures of phalanges or metacarpals can be easily reduced but their retention in the reduced position is a difficult matter, especially when there is local comminution In the presence of extensive soft tissue injury reliance on plaster fixation for fractured hand bones has in the past necessitated much compromise in reduction and fixation This in itself has made stronger the indication for amputation in border line decisions. To-day plaster as the sole means of fixation should be used only in cases of undisplaced fractures or those easily maintained in correct alignment in the position of rest Furthermore a plaster must not hide or prejudice the possible complications of soft tissue damage or its repair In the absence of these conditions as is common in this class of injury the mechanical fixation of bone fragments offers special advantages and contributes to a better result. Moreover the possibilities of primary soft tissue repair, both superficial and deep are thereby extended The exact method of fixation must depend on the site of fracture and the precise arrangement of fracture lines Small metal plates with screws (Fig. 88) circumferential wiring (Fig. 89) and longitudinal intramedullary wires (Fig. 90) each have their advantages

Intra articular fractures raise particular problems. Even here we consider that plate or wire fixation in selected cases especially about the carpo-metacarpal and metacarpo-phalangeal joints of the thumb gives better results than accrue from imperfect reduction hopeful acceptance of arthritic sequelæ and thankfulness for any useful range of movement (Fig. 91)

Repair and Closure —Opportunism is the password in closing all residual open areas for which direct suturing is not applicable. It is for this reason that it is so important not to discard any soft tissue flap or finger remnant which is viable in the early stages of operation Filleted soft tissue flaps from amputated fingers or stumps are of inestimable value in many of these cases The soft tissue remnant of one finger often makes practicable the conservation of length in a neighbouring finger

Even if there seems no immediate use for an apparently functionless stump or a soft tissue remnant, it is often wise to conserve this for future use in relation to secondary repair work For more extensive areas of skin deficiency where filleted flaps from amputated and damaged fingers are not available, direct flaps from remote areas are required These are usually needed where several fingers have been amputated through the metacarpal head regions, leaving a large open wound with bony exposure. Free grafts are sometimes directly

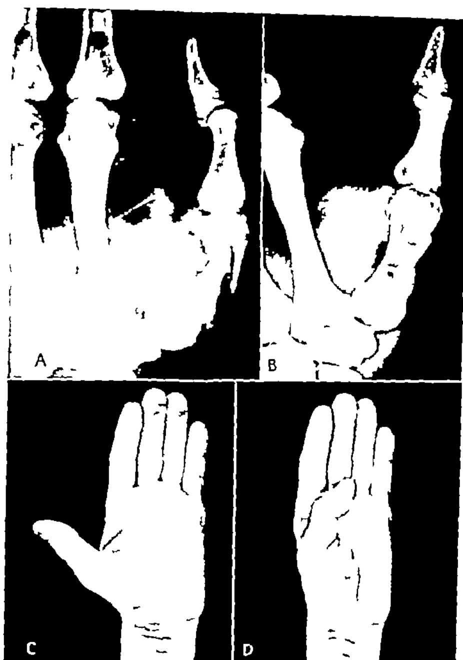


FIG 88

A recently healed compound fracture of the thumb metacarpal caused by an axe wound Only the skin had been repaired

A. There was gross displacement of the fracture with a proximal fragment presenting into the thumb web, and both extensor tendons of the thumb were severed.

B Open reduction was carried out two and a half weeks after the injury when the fragments were held by a metacarpal plate and both extensor tendons were repaired with silk after covering the plate with a soft tissue plane

C D Show the range of function six months after injury

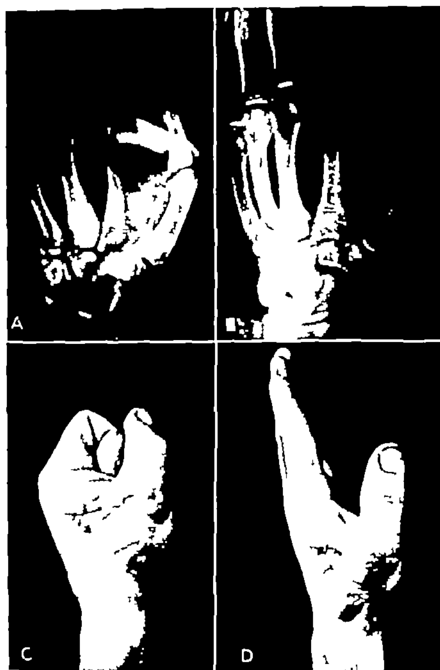


FIG. 89

Primary fracture fixation by wiring in a severe compound power saw injury

A, Shows comminuted fracture of the index metacarpal There was an overlying skin and soft tissue loss and both extensor tendons were severed.

B C, D Show the result two years after the primary and only repair operation when the fracture was reduced and fixed by circumferential wiring, extensor tendons were repaired and the area covered by a local flap with split-skin grafting of the residual defects.







FIG. 90

Primary fracture fixation by intramedullary wire

A, A compound injury with extensive soft tissue damage and unstable fractures of the metacarpals.

B Pre-operative radiograph.

C, Radiograph with the hand in plaster following soft tissue repair and fracture immobilisation with intramedullary wires inserted through the heads of the metacarpals with the fingers in the flexed position.

applicable to residual defects, and again on secondary defects if local flaps can be transposed over areas of exposed bone.

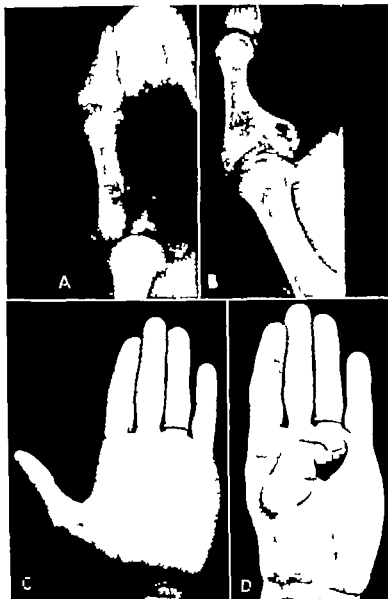


FIG 91

The intra articular fracture problem

A, A compound injury in the thumb region including an intra articular fracture of the metacarpo-phalangeal joint.

B C, D, Show the ultimate result. This would generally be regarded as good for such a fracture. The degree of thumb mobility in spite of impaired movement in the metacarpo-phalangeal joint is seen. A more accurate reduction and mechanical retention of such fractures should nowadays be possible, with less joint irregularity less arthritic change, and a better function range.

In designing flaps for surface repair in this type of injury great care should always be taken to make the best possible use of skin that retains normal sensation Every effort should be made to cover those areas which

normally come into contact in the actions of pinch and opposition with normally innervated skin as far as possible placing any free grafts or flaps from a distance in situations of lesser importance

DEEP WOUNDS OF THE PALMAR REGION

These, too often result from power-saw injuries at a more proximal level than the fingers (Fig. 92) They are often combined with finger or thumb amputation as part of an oblique line of section.

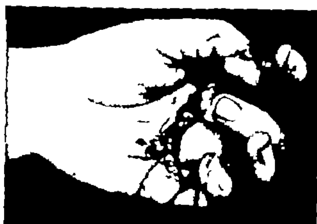


Fig 92

A deep palmar wound

The lacerating wound in the distal palm includes severed nerves and tendons. The irregular untidy nature of the soft tissue wound would contraindicate primary repair of tendons. Contrast such a wound as in Figs. 26 and 27 Chapter IV

Skin closure without repair of damaged deeper structures is the wisest primary treatment. Tissue loss is not generally confined to skin There is frequently loss of substance in nerves and tendons even before they are trimmed If the skin loss is beyond the limitations of closure without tension by direct suturing, a skin and fat flap is generally required in preparation for secondary operations to make good the defects in tendons or nerves The filleted flap of an amputated finger should be used if available, otherwise a direct flap from elsewhere is required

FLAP AVULSIONS AND DEGLOVING INJURIES

These are characteristic injuries where skin flaps, which include the subcutaneous tissue are torn off the deeper fascial planes This type of lesion is usually seen on areas where the skin has only a loose areolar connection with the deep fascia such as the back of the hand and fingers Avulsions of palmar skin are seen less frequently These injuries most commonly result from accidents with roller type or other mobile machinery (Fig 93)

Primary surgical management is based on the following considerations.

The Viability of the Avulsed Flaps—This must be decided on the principles set out in Chapter V remembering that where skin has been subjected to compression injury as by roller or pressing type machinery it rarely proves viable whatever clinical impression it may give at the time of operation

At the point of impact of the force, where the surface rent is first made avulsed flaps are usually mangled beyond salvation More remote portions of the flap are often stripped cleanly from the base tissues, and if they have not

been directly subjected to compression may well be viable. The precise area of flap which survives depends on its shape and residual attachments Edges should be cut back until bleeding is noted. It is better to trim back too much than not enough before replacing any such flap It is unfortunate that most avulsed hand flaps are on a distal base and their circulation is not as good as those on a proximal attachment. If the circulation in the flap is inadequate to support its survival *in toto* the possibility of using its skin alone as a free graft has been advocated in the literature Its successful achievement in the type of case under discussion is rare, however because of the amount of direct damage to the skin. It is safer to remove the dubious flap and replace the skin loss with free graft or flap according to the indications

The Question of Amputation—Where there is circumferential degloving of skin flaps, as in the case of fingers, the question of primary amputation arises. The area denuded the number of fingers involved which fingers, the extent of other injuries and the practicability of effecting primary cover all affect the issue.

If a single finger of an otherwise normal hand is degloved, amputation is generally the best treatment—such are the defects of sensation bulk and appearance after grafting, and such are the technical difficulties and the time consumed in designing and applying flaps even under favourable circumstances It would be quite wrong, however to take this view in the case of a degloved thumb an essential member for opposition whether or not it can be flexed There can be no indication for amputation of a thumb or thumb remnant when plastic surgeons go to great trouble to restore or reconstruct some semblance of a thumb—even to the limit of transferring a toe In practice, most of the difficult degloving injuries are met when a large area of the hand and perhaps several fingers are denuded mass amputation cannot be suggested for such injuries. It is certainly possible and worth while to cover denuded portions of fingers or even whole fingers under these circumstances It is impracticable to cover them all so that technical considerations and values must be weighed to a nicety



FIG 93

A degloving injury

All skin from the dorsal and palmar aspects of hand and wrist is tenuously hanging as dead, dying or doubtful skin flaps. The surgeon should not be misled into hopeful but futile retention and suturing of severely traumatised skin flaps.

Absolute indication for amputation is stronger where there are co-existing injuries to deep structures but in the case of multiple denuded fingers even this indication must only be accepted with *reasoned reservation*

Methods of Skin Replacement in Degloving Injuries—Methods used for this purpose depend on the region which is bared the tissue exposed and whether or not repair of deep structures is indicated either primarily or subsequently

Free grafts are quite suitable for all raw areas if there are no bare tendons,

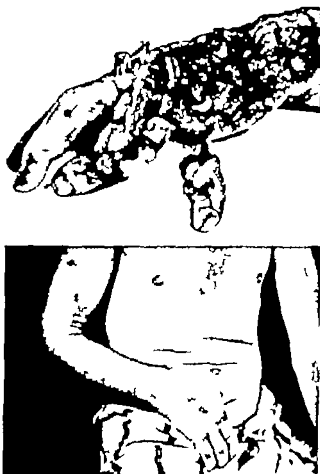


FIG. 94

Direct abdominal flap for avulsion injury

bones or joints It is usual practice to use thick split skin but for small areas especially on the palmar aspect, we have used primary whole skin grafts for this purpose Even if other forms of skin and fat replacement are subsequently necessary free grafts are usually the best and most practicable method of primary closure This applies especially for large or circumferential areas when the design of adequate primary flaps is out of the question

Flaps are indicated in cases unsuited for the use of free grafts In most cases a direct flap from a remote region is required It must be carefully designed

to ensure its safe use with reasonable comfort to the patient and to ensure that its bulk is a reasonable replica of that which has been lost. Hand flaps should not be thick, redundant masses. The best direct flaps for hand defects are those raised on a single linear attachment The common practice of "burying hands or using bridge flaps has no long term advantage. Though they might be easier to design and have a lively circulation when first raised they create difficulties at the detachment stage because they have not gained much blood supply from the recipient area Moreover their open under areas are difficult to keep clean and harbour infection. Many hands are buried under abdominal skin with little forethought relative to the end result The area of the traumatic defect covered by the flap is often but little of the total Wounds can be "buried but not covered" so that the essential problem is only postponed until the detachment phase when the defect still presents, but now as an infected granuloma These raw areas cannot be covered easily at subsequent procedures Multiple delaying operations are necessary during which time fingers become stiffer and metacarpo-phalangeal joints often fix in hyperextension because they have been lying across the abdomen in this position for weeks. To this are often added prolonged effects of inflammation and œdema

A well-designed, simple, direct flap (Fig. 94) which covers all the area of tissue loss at the primary attachment which permits of easy cleansing and dressing and which, at least after early stages permits of some movement in small joints overcomes the gross disadvantages of the "hand in pocket type of flap

There is a wide scope in the selection of donor site for these flaps The abdomen, the chest the opposite forearm and the thigh each have their advantages for particular cases. Where single fingers are concerned, the opposite forearm as a donor site offers easy posture for the patient and gives flaps of simple design and desirable thickness

COMPRESSION INJURIES OF THE HAND

With increased mechanisation compression types of hand injury are seen more frequently Of the machinery responsible, power presses head the list We have been impressed by the high incidence of these injuries in a country where secondary industry is undergoing rapid development and expansion They have occurred notably among people not used to machinery such as new migrant folk and people who have recently forsaken their erstwhile job for the easier and higher wages to be obtained from industrial work The steam laundry press is a common source of injury in this group with machines frequently controlled by teen age girls of no experience and little sense of responsibility

The severity of compression damage depends on two obvious factors

The first of these is the area of the hand which is caught by the compression force. It may only be the tip of the finger jammed in a car door or a small area injured by a falling weight, while at the other extreme the whole hand may be irretrievably pulped into a two-plane mass by a hot moulding press The latter constitute some of the worst hand injuries we see to-day (Fig. 96)

Secondly the order of force and the duration of its application influence the nature and severity of the injury received. We meet closed injuries due to



FIG. 95
Typical recent compression injuries.



FIG. 96
Hot press injury
Hand reduced to two planes by compression and heat.

compression where the skin remains intact even though it may be compressed beyond viability (Fig. 97) Bursting of the integument may occur and damaged fatty tissue may protrude through splits in the skin These splits are often seen between the webs of the fingers Another common ramification of the bursting

effect is along the flexor skin of a finger which is split longitudinally, exposing and often laying open the tendon sheath These wounds are difficult to close because of swelling and œdema, and are notorious for the degree of scar contracture and tendon fixation which follows We have rarely seen a mobile finger after such an injury

Furthermore, compression injuries are often complicated by the lacerating effects of surface irregularities at the point of impact

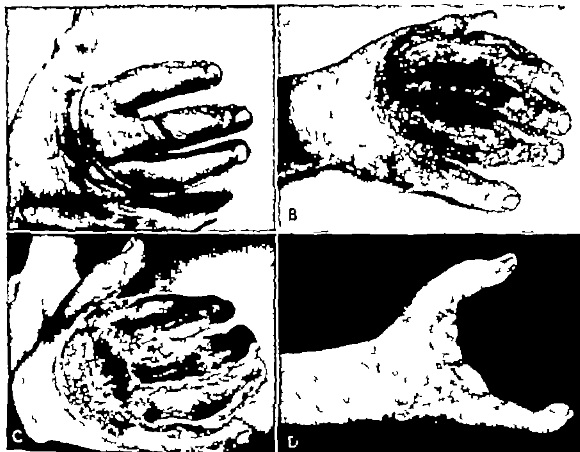


FIG. 97

Progress of a severe compression injury

This injury was caused by a plastic moulding press.

A, Shows the recent injury when viability was in doubt.
B C, Show successive changes in the subsequent two weeks when the extent of damage is declared.
D The healed hand remnant after secondary amputation of gangrenous regions and temporary split-skin grafts. The "two-pronged" hand is a common end result in these injuries.

The main decision underlying the difficult management of these injuries is that of tissue viability

In the grosser cases decision must be made between two extremes—either local amputation on the radical side or masterly inactivity on the conservative side. There is rarely any half way measure With severe injuries hopeful conservation is preferred for fear of adding any further damage by radical procedures. The ultimate viability of any given region is generally less than first appears

If the conservative line is to be followed primary treatment after cleansing should include the simple suture of skin splits and the trimming away of loose, soft tissue tags We do not advocate any purposeful excision of dubious areas or any primary grafting in this type of injury Such are the difficulties of assessing damage and so unpredictable is the fate of the insulted tissue that it is better to seek the aid of time in declaring these issues It is our experience that radical primary treatment proves either inadequate or over zealous for a region where structural conservation is so important

The hand should be *immobilised in the optimum position of function* realising that recovery may be slow and the effects of extensive deep scar formation very limiting to that recovery *No matter what the surface* appearance the prognosis must always be very guarded

Pain is a prominent feature of these injuries during the stages of demarcation and may persist for several weeks It is often very severe and requires understanding nursing and analgesia.

The Jammed Finger —This form of compressing injury is well known—the finger jammed in a door or the finger tip which is hit with a hammer It does not call for any elaborate treatment. Blood blister pulp hæmatoma, subungual hæmatoma, nail damage and surface splits call only for surface cleansing and a simple dressing, together with measures for relief of pain—the latter may involve decompression of a subungual hæmatoma by trephining. It is generally better to leave a damaged nail *in situ* as protection until the more painful stages have passed

In children before the age of fusion of the terminal phalangeal epiphysis jamming of the finger tip often results in an epiphyseal fracture which produces a deformity *closely resembling the mallet finger of extensor tendon injury* The explanation of this typical deformity is to be found in the fact that the *flexor digitorum profundus insertion extends well distally on to the* diaphysis whilst the extensor tendon insertion is confined to the epiphysis (Fig. 76)

HIGH EXPLOSIVE INJURIES

These injuries are well known in war time Unthrown hand grenades and the untimely explosions of land mines and booby traps were responsible for many mutilations in the last war Similar injuries, however are sometimes seen in civil life among munitions and chemical workers or from mining and blasting accidents (Fig. 98) As most of these injuries occur unexpectedly during the handling of explosive agents they are frequently bilateral and complicated by injuries to other regions often the eyes Blindness together with severe hand mutilation is the most pathetic combination of injuries we have to treat.

Recent high-explosive wounds of the hand present a gruesome picture The shattered hand remnants usually include uncompleted amputations where the fingers remain hanging only by tendons Bone splintering and deep, splitting clefts up the interosseous spaces are typical Charring ingrained dirt and foreign bodies add to the *traumatic melee*

The severe degree of the damage, the dubious viability of hanging remnants

and the impossibility of rendering such wounds clean and fit for closure—all make for difficult primary treatment

Anti shock treatment is required to a degree rarely necessary with most other hand injuries

After cleaning the wounds so far as practicable, obviously non-viable tissue is removed *It is permissible to leave all essential tissue of dubious nature* Primary closure is contraindicated though it is important wherever possible to cover all exposed bone especially that of amputation stumps Primary amputation of part or whole digits and occasionally the whole hand is often the only practicable means of satisfying these considerations. Beyond this

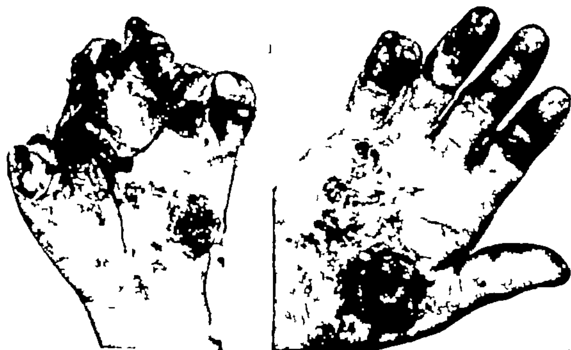


FIG. 98

A typical high-explosive injury

Both hands a few days after injury by the premature explosion of detonators. Deep lacerations with powder impregnation and irregular untidy amputations are typical.

plaster immobilisation in the position of function and antibiotic therapy fulfil the indications at this stage The importance of the optimum position for immobilisation of fingers is obvious Full function will never return to such a hand We reiterate the dangers of primary closure over any structure whose viability is in doubt These are the very cases where tension and sepsis including anaerobic infection are likely to arise.

A secondary débridement is called for when viable and non viable areas are declared Then after a short period of dressing preparation a palliative skin graft will hasten healing and minimise scar formation. If early healing is achieved bone sepsis precluded, scar formation minimised and a fair degree of mobility soon regained, then the optimum result has been achieved from the early management of such an injury

This leaves much opportunity for secondary reparative work in eradication of scar and in the possibilities of reconstruction for lost elements of function, as considered in Part IV

GUNSHOT WOUNDS OF THE HAND

A gunshot injury may produce any of the wounds already described, but the "through and through" gunshot wound of the hand warrants some description as a special type It is caused by accidents such as occur



FIG 99

A recent gunshot wound of the hand without bony damage

A "through and through" wound without bony impact may cause surprisingly little damage ultimate deformity and disability

when cleaning rifles or getting through fences while carrying arms or by self inflicted injuries.

The appearance of a through and through" wound of the hand depends on whether or not there has been bony impact (Figs 99 and 100) A bullet passing through the soft tissues alone leaves but a small entrance and exit wound and often remarkably little damage through its track More commonly however there is a small entrance wound in the palm but a large destructive exit wound caused by impact explosion and shattering comminution of metacarpal bones (Fig. 101) There is some degree of tissue necrosis along the wound track Sepsis which develops is related to the amount of deep tissue damage and whether or not some foreign body is retained

Again we have a contraindication to primary closure because these wounds cannot be made surgically clean and fit to close without a degree of excision which would add insult to injury We have had little experience of this type of wound in civilian life, but do not consider that the primary treatment would differ from that under service conditions



FIG. 100

A healed gunshot wound of the hand with bony damage

In contrast to the case in Fig. 99 a " through and through " gunshot wound with bony impact and comminution causes extensive local damage, deformity and disability Shortening and non-union in the metacarpal, a stiff metacarpo-phalangeal joint and damage or dysfunction of the tendon system result in a useless finger Early amputation is generally the best treatment for such cases.



FIG 101

Radiograph of a gun shot wound of the hand

Indicates degree of fragmentation of the missile and the extent of the bony comminution that can occur

Immobilisation of the hand is carried out after trimming of the skin wounds, laying the track open removing any loose and separated bone fragments and obviously non viable tissue Petroleum jelly gauze well placed along the wound track to keep it open and prevent pocketing, has its place.

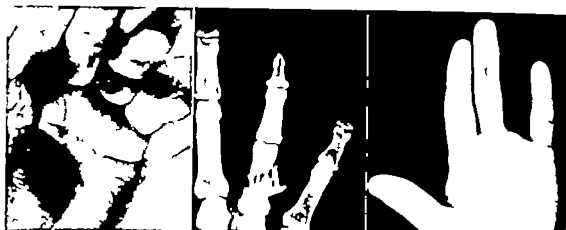


FIG 102
Primary amputation for gunshot wound of finger
There is no future in any conservative treatment of such an injury as this affecting a single finger

The place of primary finger amputation is a real one for this type of injury and may provide filleted skin flaps which are useful for replacing skin loss farther proximally If a through gunshot wound involves both flexor and extensor tendons as well as the bone of a single finger then that finger is best removed at the earliest favourable opportunity (Fig 102)

SOME LESS COMMON INJURIES

Electric Wringer Injuries—One of the recent by products of household mechanisation is the hand injury caused among housewives whose attention is



FIG 103
A household electric wringer injury
A patch of gangrene develops at the point of maximum compression

distracted when feeding the wringer from a washing machine The playful hands of children too are frequently drawn between its rollers These lesions

are sufficiently typical to warrant separate mention According to the set of the rollers and the relative diameter of hand or forearm so the brunt of a friction and compression injury is taken by different regions In adults it is generally the back of the hand while in children it is the forearm or arm which suffers.

Whether or not the skin is torn a patch of gangrene develops at the site of arrest, as shown in Fig 103 The principles of treatment follow those already discussed for compression wounds—conservation and rest evacuation of fluid under tension and secondary removal of stabilised areas of gangrene



FIG 104
Grease-gun injury
A recent grease injection injury involving deep wound in classical position on the tip of the index finger There is exposure of the flexor tendon insertion and painful swelling of the whole finger

followed by preparation of the granuloma for skin grafting The injury is generally confined to superficial tissues

Roller Press Injuries —Mechanical rollers in industry cause injuries similar in type to the above, but generally of much greater severity and not confined to superficial parts Injuries in hot roller presses, which often involve both hands, are perhaps the most mutilating of all hand injuries. An early decision with total amputation is often required when there is no chance of salvage

Grease-gun Injuries —These injuries, a product of modern industrial methods, are peculiar in their origin behaviour and the difficulties associated with their management The finger is injected with grease, at pressure about 600 lb during accidents with a pneumatic grease gun (Fig. 104) These generally involve misuse of the safety pin catch Through a small puncture wound, grease is suffused through the soft tissues of the finger and often into the tendon sheath The distension, blanching and severe pain precede deep tissue sloughing and infection associated with the foreign body and the tissue necrosis.

The early indication is to lay the finger open to decompress and remove as

much of the foreign substance as possible. This is an ideal, for prolonged sepsis, deep scarring and loss of tendon function are common sequelæ (Fig. 105).



FIG. 105
Late result of grease injection injury
A, The late effect of such injury with tissue loss, tender scarring, and impaired function.
B, A cross-arm flap was used in this case with the result shown.

It is sometimes ultimately necessary to replace scarred painful soft tissue by a flap at elective secondary operation when sepsis is quiescent Finger amputation is the alternative which exists, and each be judged on its merits

PART THREE—Chapters IX and X

INTERMEDIATE TREATMENT

INTRODUCTION TO PART THREE

IN general the recovery of function after any wound is in relation to its time of healing. The best results after open injury occur when repair is achieved with finality at a primary operation The economy of this to all concerned is obvious especially when compared with that of remote secondary operations in the wake of secondary intention healing.

Nevertheless *secondary treatment is often indicated whether or not primary* closure has been achieved It is our purpose to consider these delayed indications *of management for hand injuries in chronological sequence.* In so doing, certain intermediate or early phases of secondary treatment are conveniently separated from those more elective phases which concern repair or reconstruction Indeed before any secondary work can be carried out two essential conditions must generally be satisfied by intermediate phases of treatment if they do not already exist. **All wounds must be soundly healed and all joints must be mobile in so far as structural continuity will permit**

The arbitrary separation of these "intermediate" *facets of management* not only maintains a practical chronological sequence of events but it also *serves to emphasise that we are concerned here with clinical states or disorders* of the hand where timely correction is all important Intermediate treatment concerns the secondary procedures of necessity rather than those of election which are considered in Part Four

The longer a wound remains unhealed or the longer a joint remains stiff or deformed the more remote the possibilities of restoration to normality This is in marked contrast to conditions following hand injury where the stigmata of unhealed wounds and joint disabilities do not exist or have already been corrected Here time lapse is not only kindly but frequently desirable *before instituting elective repair of a non urgent nature*

There are conditions other than those of unhealed wounds or stiff joints which might *indicate intermediate or early secondary* treatment Many scar disabilities in themselves are the basis of joint embarrassment and stiffness if not alleviated early The time for secondary *correction of a scar disability* in this case is quite different from that of a scar which does not cause much embarrassment of small joints On this understanding it is convenient however to consider all problems of scar replacement together in Part Four

CHAPTER IX

UNHEALED WOUNDS OF THE HAND

MANY secondary procedures are needed because of breakdown deficiency or neglect of primary treatment on the lines already emphasised In some cases the reasons for failure of primary healing are avoidable, but this is not always so It would be easy but unfair to dismiss this group of cases by saying that they are better prevented by correct application of primary methods

The optimum primary treatment for a patient under some conditions is not always the same as that called for under ideal conditions Local facilities may have been inadequate for the ideal primary treatment The case may not have reached proper medical attention within a reasonably safe period for the execution of primary closure In certain injuries, by their very nature the question of viability of valuable structures is *sub judice* Wounds produced by explosives, gunshot wounds and many other gross destructive injuries are in this class where primary closure may be contraindicated Under war time conditions these factors have special application and may even dictate general policy Moreover there may be other injuries some of which may call for more exacting and time-consuming management. The patient s general condition may not always permit of ideal primary management— A living dog is better than a dead lion

Furthermore, mistakes are always with us and we are all prone to make them This matters little, providing they are realised

Whether failure of primary healing is due to avoidable or unavoidable reasons it gives rise to similar problems most of which are corollary to the secondary intention healing process of open wounds Infection scar formation and contracture, joint stiffness and structural fixations are some of them

Injured hands may be seen for the first time by the surgeon at any stage in the course of secondary healing and its varied complications In practice they commonly fall into one or other of the following groups

RECENT UNCLOSED WOUNDS

A wound may be seen first when it is too late for safe primary closure when time lapse or local appearance would suggest or indicate that infection is already established In these cases temporary expectant management should be instituted with a view to secondary closure. The principles of such expectant treatment are full antibiotic therapy immobilisation in the position of function and limited secondary débridement in so far as obvious dead tissue or foreign bodies are concerned When it is obvious from the patient s general condition and the local appearance of his wound that spreading tissue infection is not going to arise or having arisen is now under control one of three courses may be considered (1) Small wounds may be left alone

for spontaneous secondary healing if it is obvious that this can be achieved in a reasonably short time *i.e* when no obvious advantage would be gained by secondary surgical closure (2) A very occasional hand wound may require secondary suture This should be done under general anæsthesia, when wound margins should be lightly trimmed and reconstituted and enough lateral mobilisation effected to achieve atension closure A prime condition for secondary suture is that there be no skin loss The indications for secondary suture of hand wounds are few and far apart Undue emphasis is given to this procedure in most surgical literature. (3) Early secondary grafting is indicated for all wounds with skin loss relative or absolute where healing time could so be reduced A wound which could be closed by direct suture at a primary procedure before swelling, reaction and fixation of wound edges by granulomatous tissue, can always be closed more suitably by secondary graft than by secondary suture Secondary suture necessitates more local interference than does secondary graft

Although the place for secondary closure of hand wounds in civil practice is a very limited one it must not be forgotten It might well again become a method of choice in war time Modern advances in technique require certain conditions for their safe application and these may not always obtain under conditions of war

MASSIVE TISSUE NECROSIS

This often occurs when wounds have been sutured without proper assessment of viability at a primary operation It manifests the predicament of the surgeon who has been taught the principle of primary closure without being taught how it can be achieved Without such technical knowledge he would do better to continue with open methods of wound management

Again in many crushing injuries tissues of dubious viability or which perhaps appear viable to ordinary tests at an initial operation often fail to survive subsequently

The particular indications in dealing with established tissue necrosis are best considered in two phases —

1 The region should be freed from any tension immediately Tension may have instigated tissue necrosis and its further increase as septic reaction and œdema ensue then embarrasses the circulation in adjacent areas. This type of mass necrosis is often in good faith ascribed to infection whereas on the contrary in most cases death of tissue comes first and infection follows Such infection is often anaerobic and saprophytic. This vicious circle of tension necrosis, sepsis and more tension must be broken by cutting or removing stitches from appropriate regions It is sometimes difficult in early stages to determine exactly which areas are viable and which are not This is important especially if the doubtful skin areas cover vulnerable structures. It is generally best to continue expectant treatment in dubious cases for a few days after relieving tension until demarcation lines are obvious between live and dead

tissue If the dead tissue is clean and dry it might well be left even longer (Fig 106) Any more radical approach may involve the removal of more tissue than necessary and may well jeopardise the viability of a deeper structure or *a distal area—a finger* for example This problem has particular application in relation to certain local deep burns

2. When the extent of tissue necrosis is obvious, dead tissue is best removed with scissors or a sharp knife at a secondary *débridement* operation under general anæsthetic This may involve finger amputation through a joint Preparation of any exposed area for early grafting should then be instituted With large raw areas it is unnecessary to postpone secondary grafting until all local dead tissue, such as bone or tendon, is removed if the latter is confined to a particular area which can be left unoccluded when covering the main granulating area with skin



FIG. 106

Massive tissue necrosis

In many severe injuries only time will finally establish which areas are viable and which are not. With sepsis under control it is better to wait until dead areas are well demarcated and can be separated with minimum disturbance of viable regions. These two hands show stages in the declaration process

A, One week after injury in a cardboard pressing machine.

B, Two weeks *after crushing between rollers.*

EXPOSURE NECROSIS

When, in an open wound tendon is devoid of its sheath or bone devoid of its periosteum and soft tissue coverings, the blood supply of their exposed surfaces gradually fails and superficial necrosis commences This process normally aggravated by the onset of sepsis, often spreads deeper as in the case of exposed tendons As the surface shreds off it leaves another to the same fate

In the early history of a wound when these exposed structures are obvious and as yet not necrotic, the effects of failing circulation can be offset by covering the area with a skin flap from some local or remote region This has special application when there is extensive skin loss or necrosis on the back of the hand

Once necrosis is established, *i.e.*, when the tendon loses its sheen and its surface commences to flake, or when bone takes on a dull yellow colour these tissues are far beyond salvation and only expectant treatment can be instituted

until the extent of the necrosis is obvious Unfortunately this is usually a slow progressive and spreading change The rate of separation varies widely from structure to structure and from region to region When the necrosis is demarcated, tendons can be actively cut away In the case of bone it is better to remove sequestra only in the later stages of their declaration and formation. If any attempt is made to separate sequestra prematurely with sharp instruments a repetition of necrosis from spreading of sepsis is always likely

GRANULATING WOUNDS

If primary closure is the main object in primary treatment of hand injuries it might well be stated that earliest possible epithelialisation is the main object of secondary treatment for all open granulating wounds. The proper early healing of soft tissue wounds is an essential prerequisite for early active function and to minimise the pernicious effects of scar formation The early lines of treatment for all open granulating wounds are the same whether the immediate object is spontaneous healing or active grafting. The optimum requirements are the same in either case A skin graft is merely a superadded indication if the wound is of such a size that appreciable healing time can be saved To this end no matter what the ultimate requirements of the particular area might be a few pinch grafts or a split-skin graft on a wound the size of a postage stamp should be considered as a routine dressing as soon as the granulating surface is conditioned Students and house surgeons should be proficient in these simple procedures at an elementary stage of their surgical training.

In the preparation of open granulating wounds whether grafting is anticipated or not treatment should be conducted with a bacteriological conscience. It includes daily cleansing local application appropriate to the state and type of wound infection and a pressure dressing. Cleansing and lavage are easy in a hand bath when soap can be freely used with advantage *The mechanical removal* of bacteria and nutrient media by simple soap and water washing is by no means the least important part of a wound toilet The *application of antiseptic* agents at repeated dressings over inspissated pus and debris is all too common

Where discharge persists to a degree incompatible with grafting the possibility of a retained foreign body necrosis of bare tendon or bone or of an open joint should be considered Any of these may act as a persistent focus for reinfection of a wound surface. The characteristics of healthy granulation are its bright colour its firm regular surface with minimal discharge and an actively growing epithelial edge (Fig 107 A and B) A granuloma over which centripetal edge-growth is rapid is a satisfactory base for a skin graft

As soon as surface healing is achieved these wounds may call for further secondary treatment on lines considered under other headings



A



B

FIG 107

Preparation of granulating wounds for grafts

A, Two residual wound areas after a hand injury Contrast their suitability and preparedness for secondary skin grafting. The palmar wound, a flat, clean, regular granulating surface has an indeterminate and actively growing edge and is ready for skin grafting. The wrist wound with unseparated slough and free discharge has a regular defined and inactive edge and is yet quite unsuited for grafting.

B, A close-up view showing the active growing epithelial edge—fair assurance that a graft will take.

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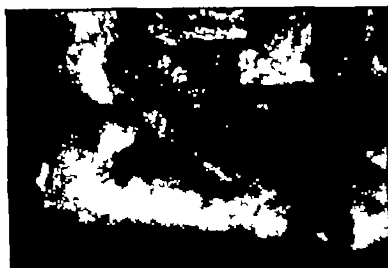
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SEPTIC COMPLICATIONS

It is a paradox that septic complications usually follow the more simple injuries of the hand and fingers as the result of their neglect or improper management, usually the fault of the patient himself

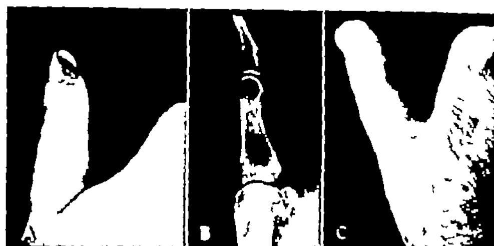


FIG 108

Osteitis of phalanx from exposure and sepsis

A common result after failure to achieve primary closure for an open injury of the finger tip with bone exposure.

A The chronic painful discharging wound.
B, Radiograph of the underlying phalanx—one year after the initial injury
C, The result of excision of the area and its replacement by a direct flap from a useless deformed little finger subsequently amputated.



FIG 109

A chronic unhealed finger wound

A, Painful discharging wound of two years duration.
B Condition *two months after pulp replacement by* a direct abdominal flap.

The septic complication of most concern to-day is that of osteomyelitis in exposed bone areas. It is usually on the tip of a finger or finger stump where primary closure with a soft tissue flap has not been achieved (Figs 108 and 109) Expectant treatment is better than any premature attempts at proximal section

through bony structure The risks of further sepsis at the site of the proximal section are great, and their effect embarrassing to all concerned It is better to accept long delay and the fact that secondary amputation or plastic reconstruction will be necessary for an adherent scar which is often painful and unstable. Earlier interference is permissible, however if the length and condition of the bone ends are such that proximal amputation through a joint can be carried out.

Under present-day conditions spreading infections in tendon sheaths and fascial spaces are less common and their effects are less disastrous These complications are well covered in many standard books The principles of their management include immobilisation in correct posture antibiotic therapy drainage in proper time and place and sometimes later removal of dead tissue.

CHAPTER X

RE-ESTABLISHMENT OF JOINT MOBILITY

THE elaboration of any reconstructive surgical programme is largely *conditioned* by the presence of adequate joint mobility. If mobility is not restored to the small joints of the hand *many secondary reparative* procedures are worthless or indeed contraindicated unless they are directed to removing the cause of joint embarrassment.

The small joints of the fingers do not tolerate prolonged fixation or postural deformity without suffering changes or fixations in the delicately balanced arrangements of their articular and periarticular structures.

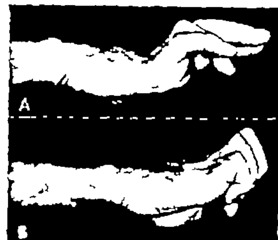


FIG. 110

Knuckle hyperextension deformity

The vicious deformity to be avoided by careful posture and splinting in all cases of dorsal hand injury or *small muscle paralysis*. The typical hyperextension deformity of metacarpo-phalangeal joints with secondary flexion deformities in interphalangeal joints is illustrated.

A, *Shows maximum extension of the fingers.*

B, Shows maximum flexion—in which efforts the metacarpo-phalangeal hyperextension is even exaggerated. The manipulative value of the fingers is lost without effective thumb opposition.

Postural fixations and deformities, whatever their cause, are prone to become permanent. The intimate relations of both flexor and extensor tendon systems to the small finger joints are liable to be upset. Such is the balance of power between flexors and extensors and so dependent is it on position variations and mobility of the various finger joints that defects in any one of these three interdependent arrangements will easily initiate secondary deformities and disabilities (Fig. 110).

The lateral ligaments of the metacarpo-phalangeal joints are prone to *shortening and contracture if these* joints are fixed in the extended position whilst the anterior capsules *of the first interphalangeal joints are* especially prone to shortening and contracture in the flexed position. The former is difficult to correct, the latter generally impossible. The influence of anterior capsule contraction of interphalangeal joints can easily be demonstrated on an amputated finger with this deformity. Whatever its basic origin such a finger cannot be straightened by strong manual force, except by rupturing or cutting the contracted anterior capsule. Even then it generally involves a dislocation of the joint.

The period for which these postural changes are reversible is alarmingly short. Age has an enormous influence on this, as on the rate and extent to which any recovery of function is effected. Anyone with an arthritic tendency is grossly handicapped in this regard.

RE ESTABLISHMENT OF JOINT MOBILITY

The importance of preventing joint stiffness is obvious No single joint should be immobilised for longer than is indicated. Where joint stiffness is apparent it may be necessary to err rather on the side of movement. One can always immobilise again if sepsis, for example is manifest but it becomes increasingly difficult to mobilise joints frozen by long inactivity

The metacarpo-phalangeal joints are the key joints in the hand, and there are few surgical conditions which ever justify their immobilisation in any other than the position of function. At the interphalangeal joints three weeks is a general working limit for immobilisation in other than the position of function. This may apply for example to the extended position following repair of the related extensor mechanism

If immobilisation has been of short duration active effort and use are usually sufficient to restore movement but in many cases this is too slow and tedious, and often insufficient where multi-stage repairs have to be commenced. On the other hand, forced passive manipulations are bad for small joints Even if a good immediate passive effect is obtained subsequent active movement is prevented by pain œdema and reaction These in turn are soon replaced by fibrosis, with at best, a return to the *status quo ante* In these cases the principle of long-continued light elastic traction as elaborated and emphasised by Bunnell[1] is the best aid to early restoration of joint mobility The essential element in this is the nature of the traction. It is light, elastic and continuous and it must not be of sufficient degree to cause pain. This is quite different from intermittent manipulative physiotherapy which so often starts the circuit of painful manipulation inflammatory reaction and aggravation of stiffness

This principle makes use of a force similar but opposite to that which actually produces the deformity *i e* it supplies antagonistic action to the elastic tension of certain tendons unopposed by their normal antagonists.

There is no end to the elaboration of design in achieving elastic traction on the various joints of the hand, nor to the materials in which these designs can be executed. Bunnell has made a classic description of such splints ' to mobilise as distinct from splints to immobilise

The system should be removable and constructed in a light, non cumbersome and simple manner It should be easily adjusted by the patient himself and easy to keep clean It should be fitted to the particular requirements of individual patients We have found that splints of a universal purpose and use are generally too cumbersome or elaborate for particular cases They require a good deal of structural alteration and adaptation to fit properly and serve particular cases with comfort Individual splints can be made with ease and little expense where any mechanical laboratory or splint shop is at hand

Modern plastic materials are particularly useful for this purpose They are light, clean and easily adapted to shape and contour We have made much use of " perspex supplied in sheets $\frac{1}{16}$ in thick which are easily cut and moulded to a forearm after heating in a bunsen flame Small metal plates can be easily adapted to the wrist end of this splint for the attachment of any wire projections (Fig. 111)

[1] Bunnell, S (1946). Active splinting of the hand. *J Bone Jt Surg* 28, 4

In addition to exploiting the elastic traction effect of rubber bands arranged on fingers, much use can be made of spring steel wire (15-gauge piano wire) so bent and arranged that when a finger is slung to its end there is a continuous traction effect in a particular direction depending on the size length and bend in the wire

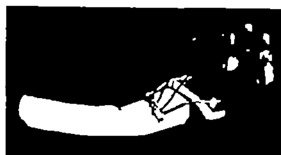


FIG 111

Perspex splint with wire extensions

The prototype traction splint for fingers stiff in flexion. The fulcrum pad controls the metacarpo-phalangeal joint while elastic tension can be applied to extend the interphalangeal joints. This type of splint is demonstrated in Fig. 83 Chapter VII

Splints for Finger Joints Stiff in Flexion — Elastic traction is obtained from dorsal spring wires fixed to the forearm splint The traction effect on particular joints is obtained by placing the fulcrum or counter pressure pad proximal to the appropriate joint (Fig. 112) As improvement ensues it may be necessary to alter the position of this fulcrum and the direction of traction as the splint illustrated easily permits

Splints for Finger Joints Stiff in Extension —Above all prevention is better than cure for this deformity Two mechanisms are often required for its correction.

Firstly for stiff extended metacarpo-phalangeal joints we have made extensive use of Bunnell's metacarpal splint [1] and its variant, the "knuckle bending" splint [2] (Fig. 113)

Secondly when and only when, some degree of flexion already exists or has been obtained in the metacarpo-phalangeal joints, a glove with elastic traction from the finger tips to cleats on a volar wrist plate is used to increase the flexion range in the interphalangeal joints (Fig. 114) It is not only useless but wrong to use this if the metacarpo-phalangeal joints are still stiff in extension for the direction of traction in relation to these extended joints will only tend to force them into hyperextension

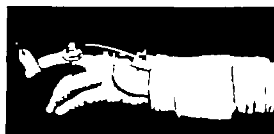


FIG. 112

Extension traction splint with fulcrum

Extension traction splint applied to a single finger Note the adjustable fulcrum pad.

(Reprint from Brit J ... Rank ...)

These prototypes of traction splints satisfy requirements in most cases Minor adjustments are always required for the individual They are applied for periods of two to three hours two or three times a day and active movements are encouraged between times. Pain is an indication to remove them and to reduce either their time of application or the tension

[1] Bunnell, S (1956) *Surgery of the Hand* 3rd ed Philadelphia J B Lippincott Co

[2] Bunnell S (1946) Active splinting of the hand. *J Bone Jt Surg* 28, 73 736

in the splint. Generally the further the joint range improves the more rapidly it does so, and joints which are going to improve commence to do so in a few days

Confronted for the first time with small joint stiffness following some hand injury it is often difficult to assess whether the stiffness is primarily due to joint damage or whether it is secondary to injury to other structures or to prolonged immobilisation In either case joint mobilisation must be restored as far as possible by the means described Comparison of active and passive movements may then give some lead to a more precise diagnosis of structural defects and the possibilities of repair



Fig. 113

Bunnell's knuckle bending splint

This simple and valuable "splint to mobilise" can be quickly made in any splint shop or laboratory At rest the metacarpo-phalangeal joints are flexed and extension exercises can be carried out against resistance and with proximal joint control This splint is most valuable in preventing claw-hand deformity during recovery of ulnar nerve lesions.

If there is no restoration of passive joint mobility any attempt at tendon repair, for example, is useless, and any skin plastic is usually only of cosmetic significance. Without adequate joint mobility the only operations of value are *those directed to the* mobilisation of metacarpo-phalangeal joints or to postural correction and fixation In such cases it becomes horribly significant just how important is the "position of function" of the hand and how reverently we must respect it in any immobilisation We can never be too busy or too proud to remake an un satisfactory plaster which does not fully respect this position



Fig. 114

Glove traction

A simple application of flexion traction. It should not be used with extended or hyper extended metacarpo-phalangeal joints as it would then tend to exaggerate that deformity It is frequently used in association with or after the knuckle bending splint.

SURGICAL CORRECTION OF POSTURE DEFORMITIES

Corrective procedures *such as* wedge-osteotomies, or joint excisions to eliminate deformities and alter alignments, *will* be considered in Part Four

Capsulotomy —There is only one soft tissue surgical procedure of value for *stiff joints* and it is of use only for a restricted group of cases. This is lateral *capsulotomy* for metacarpo-phalangeal joints which have secondarily become stiff in extension through long



FIG. 115

Lateral capsulotomy of the metacarpo-phalangeal joints

Illustration to show how the scalpel is inserted and the lateral *ligament divided at the point of its proximal origin. It is important to avoid the extensor hood mechanism* which overlies its volar and distal aspect. (Fig. 21 in Chapter II.)

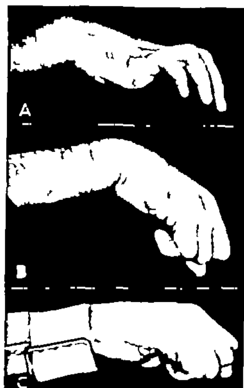


FIG. 116

Results of capsulotomy

A case of claw-hand deformity treated by lateral capsulotomy of the metacarpo-phalangeal joints.

A Shows the maximum finger flexion before capsulotomy

B C Demonstrate the flexion range some months later. The uncontrolled flexion of the wrist due to loss of wrist extensors in this case was due to damage in the forearm. Control of this by a simple splint as in C shows the true range of finger flexion resulting from the capsulotomy operation.

fixation in the extended position[1] (Fig 116) This often follows the too far distal extension of a volar plaster slab for wrist fixation Metacarpo-phalangeal joints are notorious for this deformity, and always difficult to re-mobilise

We have described how the lateral ligaments of the joints are taut in flexion and slack in the extended position and how lateral mobility which is relatively free in extension becomes restricted in flexion As with many other joints, if the slack is taken up by fibrosis and contracture, as it is with any long immobilisation in extension, it becomes obvious why flexion is impossible, and why too, the condition is so resistant to non-operative treatment This is the rationale of lateral capsulotomy which may produce a dramatic immediate result Improvement is then maintained by careful and frequent physiotherapy based on assisted active movements. The ligaments are sectioned through separate tenotome stabs on each side of the extensor tendon The operation may be done as an open procedure with a more radical resection of the ligaments. It is sometimes combined with more extensive dissection and freeing of adherent planes between the extensor system and the joint or proximal phalanx The precise indications are varied.

Apart from lateral capsulotomy for metacarpo-phalangeal joints, we have had no success from a number of operative procedures tried in relation to other soft tissues of the small hand joints.

Though we have indicated the active procedures of value in restoring joint mobility in particular cases, let it not be thought that such surgical activity is always essential in this phase of management On the contrary it is lapse of time together with quiet encouragement of normal use and function which lay the basis for return of freedom to stiff joints.

[1] Shaw C G (1920) Ankylosis of metacarpo-phalangeal joint. *Med J Aust* 2, 549

PART FOUR—CHAPTERS XI TO XV

SECONDARY TREATMENT OF HAND INJURIES

INTRODUCTION TO PART FOUR

THIS section is concerned in the main with elective secondary repair operations on hands already healed and in proper state for any such operation but this, too must be properly regarded as an arbitrary arrangement

It is one of the objects of this book to show how the need for secondary operations after hand injuries will continue to diminish with improved technical standards of primary treatment and an increased repair-consciousness *ab initio* With this, the distinction between primary and secondary surgery becomes less definite There can in fact, be no rigid line between primary and secondary repair Not only must primary treatment anticipate the possibilities of secondary repair and lay the best foundations for it, but many secondary procedures are actually commenced at a primary operation

Our object here, however is to cover those secondary repair operations which are deliberately considered and planned on the healed hand.

These may conveniently be subdivided into repair operations and reconstructive operations. The former concern the correction of defects existing in one or other of the various anatomical structures of a hand or hand remnant. The latter concern the reconstruction of or substitution for parts *actually lost.*

The succeeding chapters will follow these lines, and it is assumed that the *hand is already in optimum condition for any such operation in the light of* intermediate treatment, as already discussed

CHAPTER XI

GENERAL CONSIDERATIONS OF SECONDARY TREATMENT

REVIEW OF THE RECENTLY HEALED HAND

WHATEVER may have been envisaged at an initial plan of management every injured hand must be reviewed when all wounds are healed and joints mobile. New factors demand thought at this stage before any secondary repair is undertaken This review should embrace two main deliberations—the physical state of the hand and its efficiency

The Physical State of the Hand—Each case presents a new objective surgical problem concerning deformity, impaired movement abnormal sensory function or instability of recently healed areas. Function may fall short of the optimum for reasons of skin loss scar fixation tendon bone or nerve injury Anatomical diagnosis must be established as far as possible concerning the exact nature and amount of tissue loss in each of these structures. This is apparent to close scrutiny except in regard to tendons and nerves where it is often quite impossible to ascertain, until surgical exploration, the exact nature of damage. It is true that we may have the notes or first hand experience of primary treatment, but to the primary injury has to be added secondary damage from exposure sepsis prolonged immobilisation or scar fixation

The Efficiency of the Hand—This must be carefully considered both in relation to the likely value of any further surgical procedure and to the likely influence of passage of time and normal resolution processes The prognosis with further surgical treatment must be compared with that based merely on passage of time Much will depend on the patient s attitude, his age his normal or anticipated employment Moreover decisions cannot be divorced from personal experience in the past management of a particular patient, his co-operation and behaviour The important principle of **continuity in treatment** is again emphasised

The more mutilated the hand the more important even a slight possibility of improvement becomes, but it is unfair to commit any patient to equivocal surgery which though academically interesting, holds no real economic prospect for him There is no excuse for adding further risk to the embarrassment of his existing state

Trial of Function—The likely degree of spontaneous improvement in function often cannot be judged without the trial of time. It is often sound practice to procrastinate and allow a reasonable period for trial of use. After this the patient himself is usually a good judge of the likely value of further treatment He is the only judge of the order of his existing handicap Passage of time in one case may bring relief to a tender scarred area In another it may only manifest its instability and unsatisfactory nature. Decisions for proximal re amputation of fingers are often best made in the light of the patient s own experience over a trial period

RECORDS AND REPORTS

Records in this phase are important for future comparison and as a basis of report for insurance or litigation purposes. To maintain a fair degree of

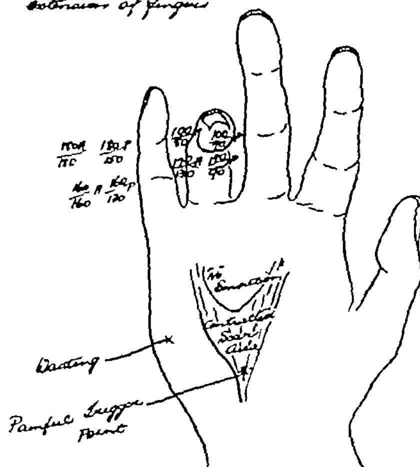


Fig. 117

Record of a hand injury

A direct tracing with appropriate annotation is a simple and accurate clinical record of deformity and dysfunction after hand injury

accuracy and to obviate the necessity for long tedious, wordy descriptions the common practice of making a direct outline tracing of the extended hand

as a basis for noting its deviation from the normal is commended (Fig. 117) So is the practice of Koch and Mason[1] of Chicago in expressing joint range as a fraction the numerator for maximum extension and the denominator for maximum flexion of the joint. The figures express degrees of posture so that 180 degrees is the straight position A record or report based on such a diagram gives a clear and more accurate statement than a word picture which of necessity if complete would be ponderous.

[1] Koch, Sumner L. & Mason, Michael L. Personal communications.

CHAPTER XII

SCAR DISABILITIES OF THE HAND

SCAR *tissue by its very nature and behaviour and by its secondary fixative* effect on deep structures is a common cause of residual hand disabilities after injury These depend on the distribution and amount of scar in superficial or deep tissue planes Limitation of movement repeated or persistent ulceration and pain are the common clinical features of unsatisfactory scars

Certain generalities are fundamental to the understanding, prevention and management of all scar disabilities

Scar is a monument to the secondary intention healing process, part of the mechanism of which is progressive diminution in the size of a wound by contraction of maturing granulation tissue Progressive local fibrosis with distortion of surrounding mobile structures is part and parcel of this process. To these issues the small joints of the fingers and the many structures contained in the hand are peculiarly vulnerable If the secondary intention healing process can be cut short or even prevented residual scar disabilities must be *correspondingly diminished*

As secondary intention healing is a common manifestation of uncorrected skin loss, the full value of primary grafts for wounds with skin loss or early secondary grafts in cases unfavourable for primary closure becomes obvious

Surface scar with its structure of an epithelium tenuously attached to a fibrous base has little of the structure and stability of true skin where a serrated basal layer is firmly attached to an elastic dermis containing many structures. **Skin is an organ with many functions , scar at its best is a make-shift integument** (Fig 118)

There are a number of misconceptions in regard to the behaviour of scar which must be laid like ghosts

The contraction of maturing scar tissue cannot be effectively prevented by external splinting—for a number of reasons (Fig. 119)

1 The effect of such splints is only upon the posture of the joints *which are included within the splint They exert no control over soft* tissue tension and elasticity nor do they influence the posture of more proximal or more distal joints. No matter what the position in which the joints are splinted the scar continues to contract at the expense of a steady stretching of the surrounding normal soft tissue *with its inherent* elasticity

2. To be effective the splint would have to act continuously from the very commencement of the healing process until the contractile phase was over—a minimum period of three months. Its removal during this period for dressings or other purpose is followed by such rapid contraction

that even after a few minutes it may be impossible to re apply the splint without manipulation Such manipulation of course, only ruptures the maturing scar and starts the process all over again

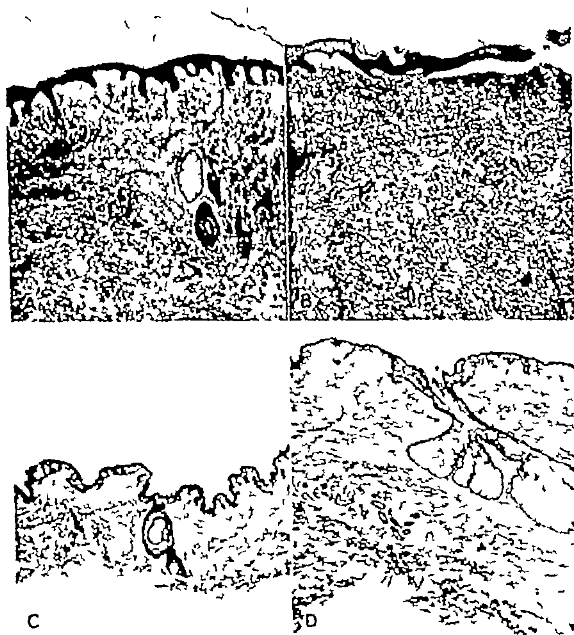


FIG 118

Comparative histology of skin, skin grafts, and scar

Histological structure of A skin B, scar C, split skin and D a healed split-skin graft. It is obvious that D is the best substitute for A. B is a relatively poor substitute for the structure and function of A. Note the ready separation of its epithelium.

3 Scars are not always confined to one surface of a joint and the optimum position for splinting for each surface may be different. In what position would we splint in such cases or when scars are circumferential ?

4 The secondary effects on small hand joints of prolonged splinting in abnormal postures in a vain attempt to control scar contraction are such that even could the primary effect be achieved the resulting joint stiffness could never be relieved



FIG 119
Contracted finger scar following a childhood injury
No effort of splinting could have prevented this deformity

Mature scar cannot be stretched either actively or passively Scar contains no elastic tissue and when matured it is one of the strongest and most inelastic tissues in the body In the early stages after wound healing the surviving tissues in the region are still in a state of subsiding inflammatory reaction which may take months to undergo slow resolution Such tissue however is capable of complete resolution and restoration to normal The scar on the other hand, which represents tissue loss and not reversible tissue damage remains and contracts progressively in its maturation to adult fibrous tissue. As the surrounding inflammatory reaction subsides, the tissues affected recover slowly their mobility and elasticity so that whereas they were previously rigid they can now be stretched to the limit of their elasticity Similarly progressive resolution allows more mobility of the subcutaneous tissue, so that the scar and its surroundings may be raised up in the form of webs across the flexor surfaces of joints This resolution in surrounding tissues may outweigh in effect the contraction of the scar and if so joint range will *increase to a degree during this period It is the surviving tissue returning to* normality which stretches—never the scar

The only effect that manipulation can have on scar is to rupture it Any forceful manipulation to be effective, must rupture both scar and surface, *and this only aggravates the vicious circle of scar formation.* Slow traction may stretch normal tissues to the limit of their elasticity but this is only temporary until the traction is removed If a return to some degree of function is achieved in this way at the expense of a minimum of stretching, deformity *or webbing of surrounding skin the method might* have an occasional application but never let us think we have stretched scar tissue

The malicious effects of scar are relative to the particular area involved The correct and timely management of a scar contracture reaches *its acme of importance on the hand* where a small scar can produce a large disability

Any linear scar will contract along its length Even the best linear scar following primary healing of suture lines can produce some disability if the *scar crosses the flexor surface of a joint These are not monuments to secondary* intention healing, but they demonstrate the vulnerability of the hand with its many small joints to any misguided surgical attack Our concern is for better **scars in better places**

Surgery concerned with the relief and replacement of scar tissue is generally

best deferred until the normal resolution processes are well advanced and the region is soft and pliable This, however cannot always be applied in the case of the hand Irretrievable secondary deformities of the small joints often render long-delayed corrective operations useless The indication for relief of scar deformities is in the intermediate phase of management if the scar is responsible for embarrassment of small joint function This applies especially to metacarpophalangeal joints which are deformed in hyperextension and generally associated with compensatory flexion deformities of the interphalangeal joints, which in turn are prone to early and permanent contracture of their anterior capsular regions

For any scar disability of the hand it must be decided (1) whether or not correction is indicated (2) when correction is best carried out (3) how scar replacement is best achieved

These factors will be considered seriatim.

THE INDICATIONS FOR SCAR REPLACEMENT

The main indications for scar correction are as follows (1) To relieve deformity and limitation of small joint movement (2) to relieve tightness and constriction which embarrass movement or circulation (3) to relieve pain in scars adherent to bone or nerve ends, (4) to replace areas prone to instability and repeated ulceration (5) to permit of operations on deep structures which would otherwise be precluded or jeopardised in a scarred area—this often applies in relation to secondary repair of tendon or nerve, (6) occasionally for cosmetic considerations.

Most of these indications no longer apply if irretrievable secondary or associated joint disabilities are already established

THE TIME FOR SCAR REPLACEMENT

The optimum time for operating on hand scars varies with their location and nature, and with the disability which exists in any given case. If there is marked joint deformity everything is to be lost by delay In most other cases much is to be gained by deferring operation until scars are well resolved and some function restored to the hand as a whole.

For scar corrections preparatory to repair of deep structures the time indication is mainly governed by the particular structure involved and the nature of the procedure envisaged

THE METHOD OF SCAR REPLACEMENT

The ideal surgical management is total excision of the scarred area to re-establish the primary anatomical defect followed by replacement with new tissue in like kind and amount to that which has been lost.

In the case of cutaneous and superficial scar this ideal can usually be reached but where there are deep scar ramifications, compromise must usually be accepted

It has often been said that a scar can be replaced only by another scar

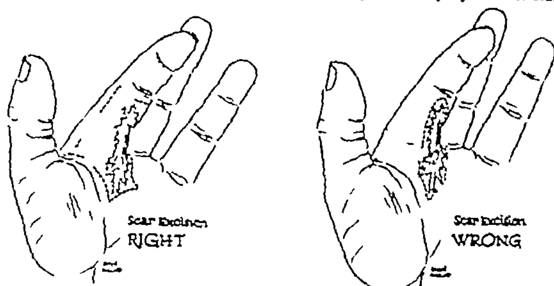


Fig. 120

The method of scar excision

It is important that any potential scar about the edge of the graft does not reproduce the original scar disability

(Reproduced by permission from Aust. and N.Z. Journal of Surgery, Vol. XII, No. 3, Sept. 1943. Scar Disabilities of Wounded Hands—Rank.)

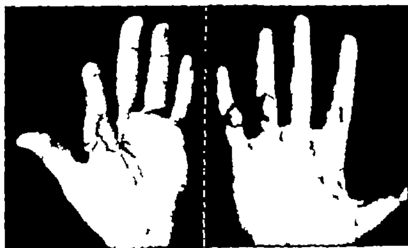


Fig. 121

Poor plastic surgery

Inadequate scar excision, wrong choice of method, badly designed flaps, are ineffective wasteful and unsightly

This may be literally true but if the new scar is of minimal amount or so situated that its contraction effect is in a neutral area and it cannot adhere to essential structures much benefit is derived

When excising a scar certain principles command respect Every endeavour

must be made to ensure that the margins of any area defect do not vertically transect flexion areas Angled incisions are better than curved incisions This often means that some normal skin must be removed to give ideal position and shape to a marginal scar The best use should be made of the neutral areas on the sides of the fingers between the extremities of the flexion creases (Figs. 120 and 121)

Compromise is necessary where deep scar envelops main anatomical structures Nerves are often contracted across areas of long-standing flexion deformity Similarly, joint capsules may be permanently contracted Despite temptation these structures must not be forcibly stretched in an effort to break down deep scarring. Their contracture should be taken as the limit of anatomical correction at the time of the scar excision A period of function in the improved range often permits of further correction where tight structures have been limiting factors at the first operation

To carry out the necessary detail of a deep scar dissection use of a tourniquet is an absolute necessity to the operation So too is familiarity with anatomical detail

Replacement of Uncomplicated Scars

We are concerned here with pure scar disabilities where there is no associated lesion of tendon nerve, bone or joint. Thus correction of the scar should entirely correct the disability Uncomplicated scars present in two main forms—linear scars and area scars

Linear Scars.—These result from wounds where there has been little or no skin loss, and where healing has been by secondary intention or linear contraction has occurred across a flexion line. Tension in itself like movement during healing, may give rise to some degree of scar hypertrophy Longitudinal scars cause varying grades of tightness or webbing which may limit function This effect is often seen on the volar aspects of the fingers or along the crests of interdigital webs, especially that of the thumb Linear contraction is usually amenable to "Z" rearrangement provided there is no appreciable loss of skin across the axis of the main scar line (Fig. 122)

In practice contracture of misplaced incision lines offers the main indication for the "Z" plastic procedure on the hand Most common of these is a so-called "lateral" incision on the finger which is too far forward of the true lateral or neutral line (Fig. 123)

Area Scars.—For all scars which represent skin loss *only* a *free graft is* indicated after scar excision. The defect is always much bigger than the area of scar excised Two types of free graft each have their particular advantages and application in covering these areas

Whole skin Grafts.—Despite their added technical difficulties and the time involved we consider that free whole-skin grafts have a value in secondary hand repair which has rather lightly been put aside because of the relative ease in using a thinner graft We continue to use whole skin for palm and volar

aspects of the fingers. Their subsequent contraction is negligible their stability is good they have an extra mobility and the order of sensation they regain,



Fig 122
" Z " plastic for linear scar contracture.

though slow in returning, ultimately becomes almost normal (Fig 124) Thinner grafts of split skin though technically easier never achieve the same

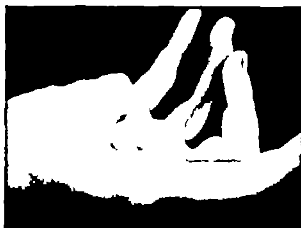


Fig. 123
Contracture from misplaced linear scars
Misplaced finger incisions are the common indication presenting to plastic surgeons for relief of linear scar contracture

high order of sensory re innervation (Fig. 125) The explanation of this may be the retention of the special end-organs free from damage in the full thickness of the dermis in a whole skin graft

Thick Split-skin Grafts.—For very large areas especially on the dorsum of the hand it is preferable to compromise in the thickness of the graft and to use a split skin graft of about three-quarter skin thickness cut with the



FIG. 124

Replacement of palmar scar by whole-skin graft

A, Scar about base of thumb and proximal palm limiting thumb abduction.

B After scar excision and whole-skin graft (Wolfe) Note relative size and outline of defect.

Cutaneous sensation, light touch, pinprick, and temperature appreciation were normal in all areas of the graft fifteen months after operation.



FIG. 125

Replacement of a dorsal scar by thick split-skin graft

A, Tight scar over the interphalangeal joint of the thumb.

B Result after wide scar excision and a thick split-skin graft.

dermatome (Fig. 126) This obviates the necessity for grafting a donor site and the thinner graft has an enhanced prospect of take. In whole-skin grafts the chance of a successful take diminishes with increase in the size of the graft, quite apart from any reason of thickness.

Exactitude of technique patient hæmostasis and a high finesse in dressing are indispensable to elective grafts of this nature if the best standards of result are expected Without these details, results can only be equivocal Even a 75 per cent take may give a relatively poor result on account of time lost in



FIG. 1_6
Thick split-skin graft for dorsal scar replacement.

secondary healing and secondary scarring in the failed area. Plastic surgery is not sound economy unless it is highly successful in more than an occasional case

Replacement of Complicated Scars

By complicated " we mean scars which are associated with damage to other structures, for which scar relief is an essential prelude to their successful repair It also includes a group of cases where scar dissection would expose deeper structures which though undamaged would provide an unsuitable base for free grafting.

Scar with Tendon Disability —If a tendon is not functioning it may have been severed or it may be fixed in scar tissue. If severed its ends may be close together in scar or they may be widely separated by retraction or by actual

tendon loss Both diagnosis and treatment can often be determined only at operation

The affected area must generally be covered by a skin and fat flap prior

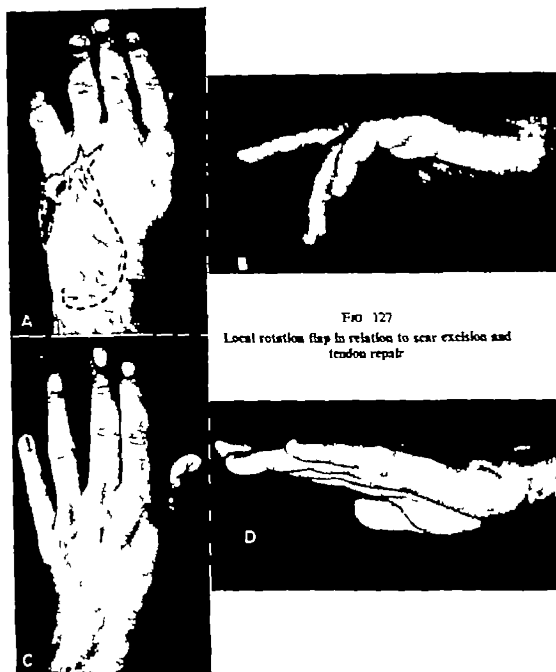


FIG 127

Local rotation flap in relation to scar excision and tendon repair

A, Healed gunshot wound with fractured metacarpal, adherent scar and tendon damage

B, Shows the loss of extension in ring and little fingers.

C, The result after scar excision, tendon repair flap cover as indicated in A All at the one operation.

to any operation on the tendons. A free graft even if it survived would only become adherent

A LOCAL FLAP if available, makes the procedure an easy one (Fig. 127)

Herein lies the value of conserving any potentially useful soft tissue at primary operations Filleted flaps from a useless finger or stump may obviate the necessity for a two-stage operation with cumbersome procedures and poses for the patient (Fig. 128)

Direct Flaps —*If local flaps are not available the scar must be replaced* by a direct flap usually from the abdomen before tendon repair can be carried



Fig. 128

The value of a filleted flap from an amputation remnant

A, In addition to the finger loss, a deep adherent scar at the base of the middle finger limits extension and tendon function.

B, Scar excision and effective tenolysis are facilitated by the availability of soft tissue flap from the short amputation stump. All such remnants should be conserved at primary treatment of any severe injury

out (Figs 129 and 130) This often means a three-stage operation as follows —

1 *Scar Excision and Attachment of the Flap* at which time exploration of the tendon deficiency can be carried out Direct flaps should be so designed that all scar is excised and replaced by the flap at the attachment operation

2 *Detachment of the Flap*—After dividing the remaining attachment to the donor site the resulting raw edge of the flap can now be sutured to the hand There is often some low-grade infection and imperfect primary healing of the detached margin Because of this, small flaps are sometimes detached and left open without reduction and setting in until after secondary healing.

3 *Subsequent Tendon Repair* transplant or graft, as detailed in the next chapter Tendons, especially as free grafts, are intolerant of infection so that

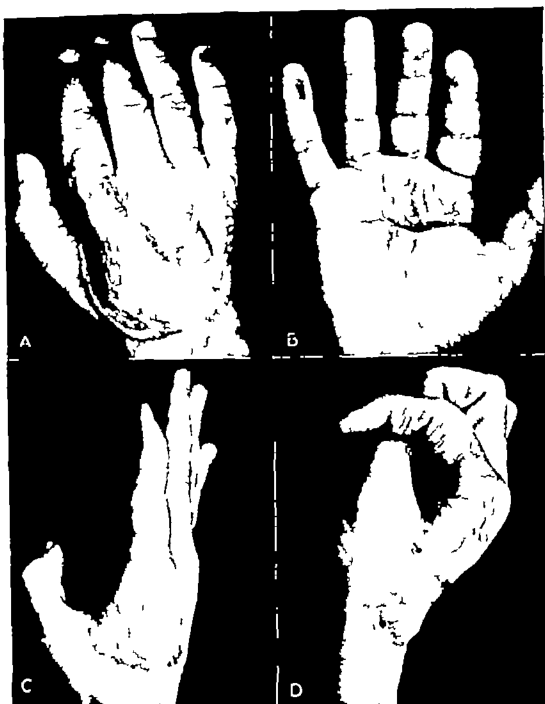


FIG 129

Scar with tendon damage

A, B One month after a severe compound injury Both flexor and extensor tendons to *the index finger were divided.*

C, D The result after soft tissue replacement by an abdominal flap, flexor tendon graft, and extensor tendon repair

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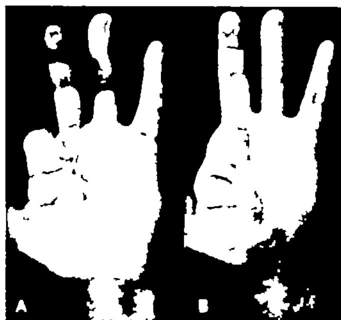


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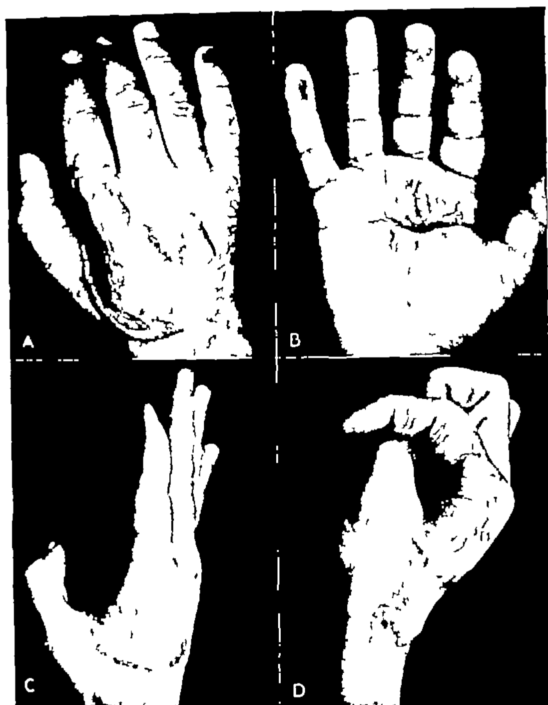


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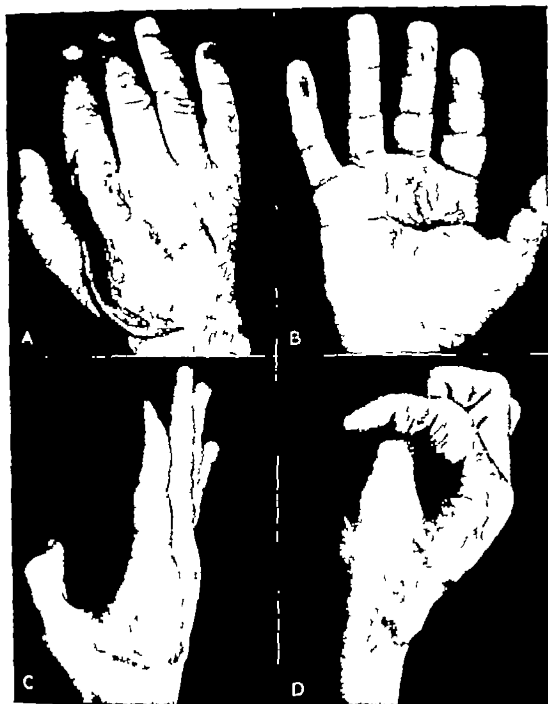


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their repair is generally better left for a separate operation when primary healing can be reasonably guaranteed. A short safety period is always preferable to premature interference and failure, as the chances of success diminish with repetition of procedure.

Scar with Tendon and Bone Disability.—The effects of sepsis are not so universally disastrous in relation to cancellous bone grafts as they are with

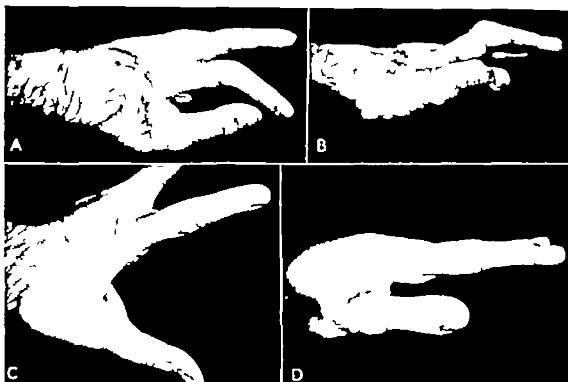


FIG. 130

Scar replacement by an abdominal flap

A, B, *Scar disability three months after destructive injury by a shell splinter. The scar was adherent* to bone stumps, fixing tendons and inducing finger deformities.

C, D. Deformity corrected and full function restored to the hand remnant by radical scar excision, bone trimming, tenolysis, and abdominal flap.

Fourteen months after the flap detachment all forms of cutaneous sensation were present over the entire cutaneous area. Light touch (von Frey 0). Tactile localisation was the same as on the abdomen but inferior to the counterpart hand area ½–1 cm. All areas were sensitive to pinprick but variable. Temperature appreciation was only crude. Sweating actively present on the whole flap.

tendon grafts. Thus where scar excision is done in relation to a bone defect the bone graft is sometimes carried out at the same operation as the flap attachment. This type of procedure has particular application to injuries of the dorsum of the hand with extensor tendon and metacarpal loss (Fig. 131). Antibiotics permit of more liberty than we were prepared for in the past. With the bone loss corrected and the flap in place tendon repairs are done at a subsequent procedure. Tendons can be run through the fat substance of a flap in a plane free from scar or bony callus.

Tendon and bone repairs are not often done at the same time as their after treatment is converse. Mechanical fixation of bone grafts, however, opens new possibilities in this regard

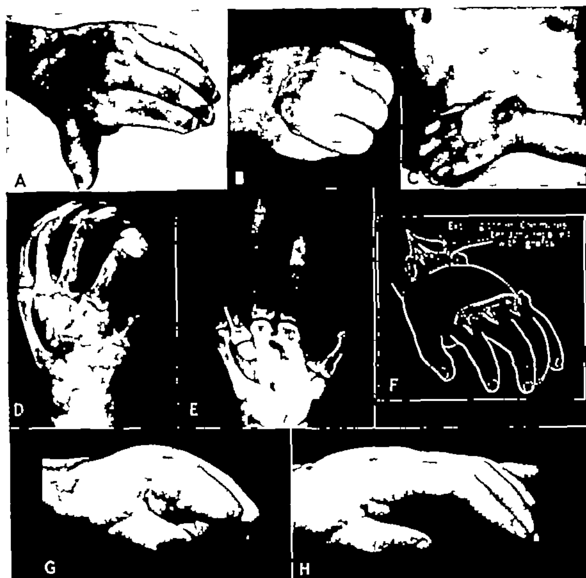


FIG 131

Scar disability complicated by tendon and bony damage

A, Six weeks after a machine gun bullet wound. There is extensive soft tissue loss, *bone loss, as in D and loss of all extensor tendons.*

B, The recently healed wound.

C, An abdominal flap attached at the same operation as bone grafting of the metacarpals to correct posture and stabilise the hand.

D E, X rays—before and after the cancellous bone grafts.

F The plan of extensor tendon grafts—palmaris and extensors of the toes were used.

G H The condition eight months after tendon grafting.

Scar with Nerve Disability —This presents the clinical problem of "painful scar" and the technical problem of repairing nerve lesions in scarred areas

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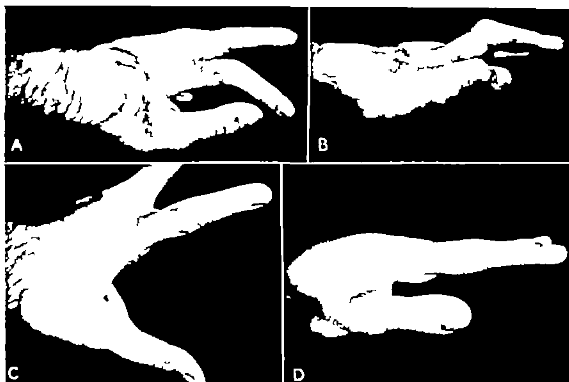


Fig. 130

Scar replacement by an abdominal flap

A, B. Scar disability three months after destructive injury by a shell splinter. The scar was adherent to bone stumps, fixing tendons and inducing finger deformities.

C, D. Deformity corrected and full function restored to the hand remnant by radical scar excision, bone trimming, tenolysis, and abdominal flap.

Fourteen months after the flap detachment all forms of cutaneous sensation were present over the entire cutaneous area. Light touch (von Frey 0). Tactile localisation was the same as on the abdomen but inferior to the counterpart hand area ½–1 cm. All areas were sensitive to pinprick but variable. Temperature appreciation was only crude. Sweating actively present on the whole flap.

tendon grafts. Thus where scar excision is done in relation to a bone defect the bone graft is sometimes carried out at the same operation as the flap attachment. This type of procedure has particular application to injuries of the dorsum of the hand with extensor tendon and metacarpal loss (Fig. 131). Antibiotics permit of more liberty than we were prepared for in the past. With the bone loss corrected and the flap in place, tendon repairs are done at a subsequent procedure. Tendons can be run through the fat substance of a flap in a plane free from scar or bony callus.

CHAPTER XIII

SECONDARY REPAIR OF DEEP STRUCTURES

SECONDARY procedures may be required either because they were postponed at the primary operation for reasons of expediency or because they could not have been successfully carried out at that time.

The first group includes the 'tidy' injuries where the deep structures should have been primarily repaired if all the criteria elaborated in Chapter VII could have been satisfied. If, however, the delay in initiation of treatment was prolonged, if the patient's general condition was unsatisfactory or if the necessary equipment and personnel were not available at the time, then delay in the repair of deeper structures may have been obligatory. In such cases we would expect the skin to have been well repaired primarily. There will be a minimum of scarring, and the time lag before the secondary operation will be as short as is compatible with sound skin healing, softening of the resulting scar and recovery of a full range of passive joint movement. This period is usually about four to six weeks.

The second group includes the 'untidy' injuries where repair of deeper structures has of necessity been delayed. Priority will have been given at the primary operation to surface repair. Here there may be loss of substance of the deep structures in mangling, avulsing and gouging injuries, which could not be made good at the primary operation.

To whichever of these two groups any particular case belongs it can now be considered to have reached the stage for secondary repair either directly or indirectly through intermediate treatment designed to bring the general state of the hand and its joints to a fit state for operative repair. It must not be assumed that such a state can be reached in any particular time nor indeed that it can be reached at all, for the worse the primary injury and the older the patient the longer the period required for scar resolution and the more insoluble the problems of intermediate treatment. Indeed, there will be some cases, particularly in those past middle age or where bone and joint damage were extensive, where the requisite conditions for secondary repair are never reached and the only decision to be made is whether to retain or to amputate a useless member. The deep structures which may need to be secondarily repaired are tendons, nerves, bones and joints.

FLEXOR TENDONS

EARLY SECONDARY REPAIR

In the first two or three weeks after a tendon injury, although the cut end is retracted, shrinkage of the tendon is usually not yet advanced sufficiently to prevent the tendon being drawn down and sutured directly. In the lower forearm, wrist and palm this will be the procedure of choice in all cases where for some reason primary repair has not been done.

Scars may be painful when cutaneous nerves bereft of their normal soft tissue covering adhere to the scarred areas The damaged nerves show various degrees and types of neuroma formation Scars are especially painful in highly sensitive areas such as the finger tip, when normal soft tissue padding is absent and scars are adherent to bone

There is a great range in the order of symptoms presented by patients with " painful scars These are frequently unrelated to anatomical findings. They call for careful assessment and management. Much vigilance and trickery are required not so much to detect the classical malingerer for he is rarely seen, but rather to assess the wide range of cause between anatomical lesions and psychic factors It is a field of psychosomatic surgery and if every case is not approached with the utmost caution, operations on painful scars will often be *meddlesome and aggravating. Nevertheless there is perhaps a tendency to-day* for over-emphasis of psychic factors, so that we often see a frankly anatomical basis for exquisitely painful scars overlooked There is no better example of this than that of digital nerve ends adherent in the terminal scars of finger stumps They may cause complete manual disablement on account of excruciating tenderness The accurate localisation of these trigger areas is the clue Resection of the nerve ends clear of the scarred area has often earned the gratitude of patients branded as neurotic

To prevent recurrence of the physical basis of painful scar a soft tissue pad should be provided over any region of nerve section neurolysis or nerve suture In a few cases a local flap will fulfil these indications but usually a direct flap is indicated This is generally done at the same operation, but where extensive bridging of nerve defects is required by grafts or transplants, a basis of fat is desirable to give such a venture the best chance of success. This means that the nerve operation should follow the soft tissue correction.

is essential to avoid any interference to the sublimus tendon in the proximal half of the finger

Frequently however the proximal tendon end will have retracted through the sublimus tunnel to the base of the finger If it can be gently threaded through the tunnel without damage to the sublimus tendon direct repair can be carried out, but if the tendon end is swollen and the tunnel narrowed it is usually not possible to achieve this result without undue manipulation and some tendon

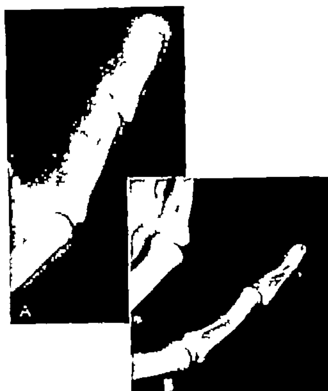


FIG. 133

Closed avulsion of the flexor profundus

A, The main portion of bone attached to the tendon can be seen at the proximal end of the finger In this case there is rather more bony disruption than usual with subluxation of the joint and multiple small bone fragments to be seen along the line of the tendon sheath. B The flexor profundus was re-attached to the terminal phalanx by a removable wire suture tied dorsally over the nail

damage. Under these circumstances the procedure should be immediately abandoned and a free tendon graft using the palmaris longus tendon should be substituted for the profundus tendon which is withdrawn through an incision in the proximal palm This free graft, being thin on section can usually be threaded through the sublimus bifurcation without difficulty and the results of this procedure are excellent

The technical details of tendon grafting are as set out later (page 186) except that in this case the undamaged sublimus tendon is left intact.

Closed Avulsion of the Flexor *Profundus from Its Insertion* (Fig. 133) — This injury in our experience almost confined to footballers results when

In the region between the metacarpo-phalangeal joint proximally and the flexor digitorum sublimus insertion distally direct flexor tendon repair is unlikely to be effective for the same reasons as set out on pages 108 and 109 and a flexor tendon graft should be carried out by the technique described later on page 186

Injuries of the Profundus Tendon Alone—In the finger the flexor digitorum profundus is frequently severed without a corresponding injury to the sublimus tendon or with only a partial sublimus injury This may occur at any point beyond the commencement of the bifurcation of the flexor digitorum sublimus over the proximal phalanx.

The problems of secondary repair vary according to the point of injury

1 If the tendon has been divided *in the proximal half of the finger* there *has generally been some damage to the sublimus tendon short of complete*

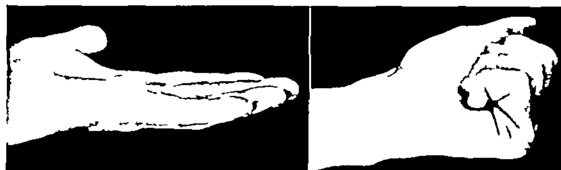


FIG 132

Secondary direct repair of flexor digitorum profundus to the ring finger in the palm

Both tendons to the ring finger had been severed in the palm and no primary repair had been carried out. Prior to operation there were a few degrees only of active flexion at the proximal inter phalangeal joint. At operation the cut ends of both tendons were found embedded in a mass of scar After resection of the sublimis tendon and secondary direct repair of the profundus tendon a full range of finger movement resulted.

division. The extent of this damage is not evident until surgical exploration is carried out, for even a few strands of intact tendon may prevent the cut ends of sublimus from retracting until union occurs and a varying degree of sublimus function may be present

At exploration there is usually no tunnel through the sublimus to be found but only a mixed mass of scar and tendon There is no prospect of successfully re-establishing the sublimus tunnel and threading a free tendon graft through it to replace the profundus tendon. In this situation therefore if the existing sublimus action on the proximal interphalangeal joint is strong and nearly complete, *it is best to make no attempt to restore the flexor profundus action but rather to stabilise the end joint in a position of partial flexion* This can be effected either by tenodesis (page 195) or by arthrodesis (Fig 164)

2. If the point of injury to the profundus tendon is *close to its insertion,* it will often be found at early secondary exploration that the proximal end has been prevented by its vinculum from retracting through the sublimus tunnel Direct suture can and should be done after resection of the tendon sheath It

is essential to avoid any interference to the sublimus tendon in the proximal half of the finger

Frequently however the proximal tendon end will have retracted through the sublimus tunnel to the base of the finger If it can be gently threaded through the tunnel without damage to the sublimus tendon direct repair can be carried out but if the tendon end is swollen and the tunnel narrowed it is usually not possible to achieve this result without undue manipulation and some tendon

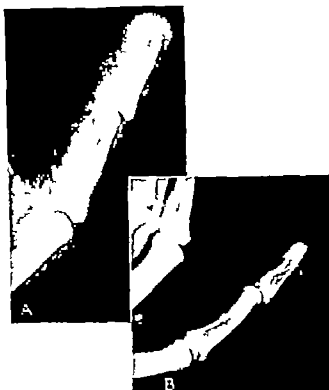


FIG 133

Closed avulsion of the flexor profundus

A. The main portion of bone attached to the tendon can be seen at the proximal end of the finger In this case there is rather more bony disruption than usual with subluxation of the joint and multiple small bone fragments to be seen along the line of the tendon sheath B The flexor profundus was re-attached to the terminal phalanx by a removable wire suture tied dorsally over the nail.

damage. Under these circumstances the procedure should be immediately abandoned and a free tendon graft using the palmaris longus tendon should be substituted for the profundus tendon which is withdrawn through an incision in the proximal palm. This free graft being thin on section can usually be threaded through the sublimus bifurcation without difficulty and the results of this procedure are excellent

The technical details of tendon grafting are as set out later (page 186) except that in this case the undamaged sublimus tendon is left intact

Closed Avulsion of the Flexor Profundus from its Insertion (Fig. 133).—This injury in our experience almost confined to footballers results when

the opponent s jersey is torn from the clutching hand at high speed The tendon fibres may be torn or more commonly a shield shaped fragment of bone comes away with the tendon and the powerful muscle contraction at the moment of avulsion pulls the tendon end right through the sublimus bifurcation into the base of the finger Pain and swelling of the finger loss of flexion of the distal joint, and tenderness along the line of the tendon sheath are the clinical features. Even at early operation the degree of tearing of the tendon end or the jamming of tendon and attached bone fragments in the proximal half of the finger may indicate its complete removal and replacement by a free



Fig. 134

The varying degree of embarrassment to the function of the flexor sublimis after section of the profundus tendon in the finger

A, The profundus tendon to little finger was cut near the proximal interphalangeal joint. Although the flexor sublimis was still in continuity the effect of scar in this region and adhesion to the retracted profundus tendon grossly limited its action. Such cases should be treated as if both tendons were cut and should be subjected to secondary tendon graft after excision of both tendons.

B The profundus tendon to the middle finger was cut more distally and in this case there was no embarrassment to the action of the sublimis tendon. In such cases the function of the proximal joint must never be prejudiced by any procedure directed to improving the range at the end joint. Fusion of the end joint in partial flexion may be the best solution.

graft of palmaris longus leaving the undamaged sublimus tendon intact In this case the graft will need to be attached to the distal phalanx by wire sutures threaded through drill holes in the bone.

Delayed Secondary Repair

When secondary repair of flexor tendon injuries is delayed for any reason beyond the first few weeks exploration will generally reveal that the proximal tendon ends are both retracted and contracted and there is no possibility of direct repair without undue tension, if at all

In the Forearm above the wrist some degree of tension and an exaggerated flexion position of the wrist can be accepted in the repair and can subsequently be corrected by slow traction after tendon union is formed In the hand, however direct repair is usually out of the question under these circumstances.

In the Palm the best procedure is probably to divide the sublimus tendon to an adjacent finger at a suitable level and transpose this on to the distal end of the severed profundus tendon provided this still moves freely in the finger

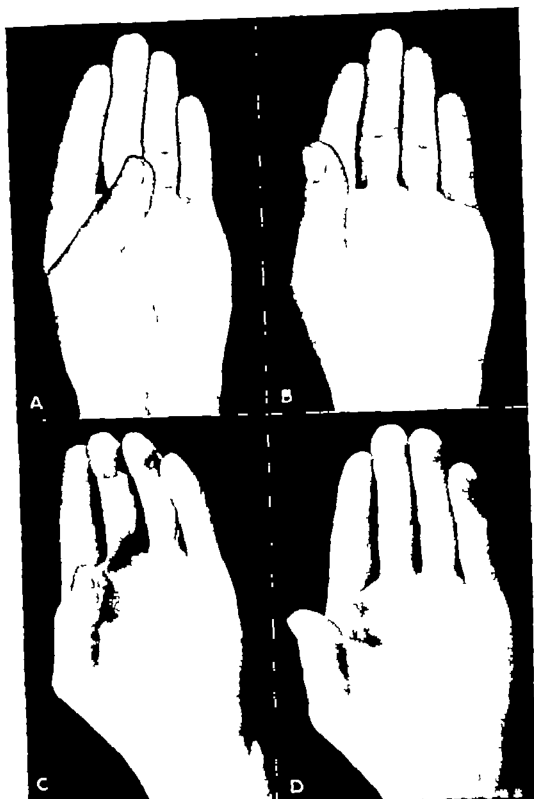


Fig. 135

Tendon transplant to restore thumb flexion

A Shows fixed adduction deformity from scar fixation at the base of thumb and thenar eminence, with no active flexion at the end joint.

B, The improved range of thumb abduction after deep scar dissection, excision of the adherent section of the flexor pollicis longus and "Z" rearrangement of the skin scar

C D Show the range of active flexion at the end joint after transplanting the extensor digitorum communis to the index finger across the thumb web, through a pulley formed by retaining a portion of the flexor sheath over the proximal phalanx, to be attached distally to the stump of the flexor pollicis longus near its insertion Free tendon graft to the flexor pollicis was in this case contraindicated by the extent of the deep scarring at the base of the thumb.

If the tendons are adherent to the digital theca then a free tendon graft to flexor digitorum profundus from proximal palm to insertion will be the best procedure

In the **Finger** between metacarpo-phalangeal joint and insertion of flexor sublimus, a free tendon graft will always be the operation of choice irrespective of the time interval that has elapsed.

Injuries of the Profundus Tendon Alone —In these cases tendon retraction, fibrosis and obliteration of the sublimus tunnel will preclude direct repair at any level if exploration is delayed beyond the first two or three weeks, and three courses are then open to the surgeon —

1 If there is a good range of proximal interphalangeal joint flexion and the patient is not greatly concerned with the inability to flex the end joint, the finger may be left alone

2. If there is a range of 90 degrees or better in the proximal interphalangeal joint and the patient requires stability in the end joint, this can be provided by tenodesis (p 195) if there is a sufficiently long distal profundus stump or by arthrodesis of the end joint (Fig. 164)

3 If the range of active flexion of the proximal joint is less than 90 degrees and a sufficient lapse of time has occurred to make further improvement unlikely it will usually be best to sacrifice this ineffective movement provided the finger and its passive joint range are otherwise satisfactory and to carry out a free tendon graft (p 186) after resection of both tendons

Complicated Secondary Repair

Tendon injuries complicated by loss of length from avulsion or mangling type of injury can be dealt with by free tendon graft or tendon transplant (Fig. 135)

When tendons are deprived of their activating units by destruction of their muscle bellies, transposition of neighbouring muscle tendon units preferably with a similar action and nerve supply is the only procedure possible

In very extensive injuries where no neighbouring units are available it may be necessary to transpose tendons from the dorsal to the volar aspect The problem then is similar to that where motor units to the fingers are inactivated by irreparable nerve injuries or failed nerve repairs.

Failed Tendon Repair

Cases of failed tendon repair are always difficult problems and often cannot be brought to a fit state for further attempt at restoration of function because of the extent of the scarring and the degree of joint fixation There are four alternatives to consider —

1 Tenolysis (Fig. 136) This procedure has a limited place in cases where adhesion of a very localised nature is restricting the "pull through" of an otherwise satisfactorily repaired tendon It may also restore full function on occasions when cross-union of partly damaged tendons has occurred in the

palm When the sublimus and profundus are joined locally in this way the removal of the sublimus followed by early active use of the finger can be completely effective.

Occasionally tenolysis can also be very useful after flexor tendon grafting if effective movement is prevented by filmy adhesions of the tendon to its thickened paratenon and to the remaining pulley system

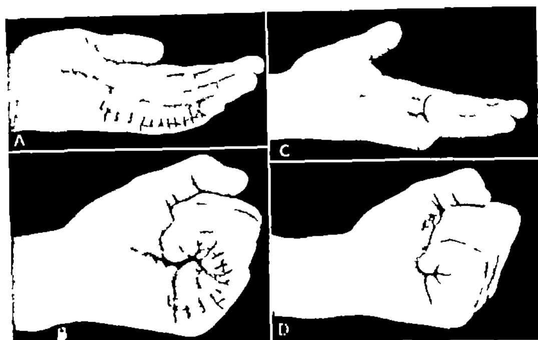


Fig 136

A B Show the range of movement in the little finger one week after tenolysis following a tendon graft to the little finger three months previously where there was no interphalangeal flexion at all preoperatively

C, D Show the range of movement two years later Note the flexion contracture of the finger and the prolapse of the tendon following destruction of the pulley system.

The best time for this is about three months after operation if there is no evidence of steady improvement in function at this time It should be regarded as an extremely delicate procedure of no less magnitude than the original tendon graft. It is carried out by gentle dissection with fine scissors under direct vision. Great care must be taken of the pulleys and the surface of the tendon must not be damaged during the process. There is no place for blind tendon stripping with any of the instruments devised for this purpose, and the best results are achieved where the adhesions are thin and limited in extent Increasing experience with this procedure in selected cases has produced useful improvement in many cases and has sometimes turned a poor result into an excellent one

Tenolysis has no place, however, where rigid adhesion between repaired tendon and surroundings extends over a wide area and where the tendon is incorporated in a thick mass of surrounding scar It is equally ineffective when the passive joint range is grossly restricted

2. Where tenolysis is not practicable, the only chance of restoring function

lies in a preliminary complete excision of the adherent tendons, followed later by a free tendon graft if and when scar resolution and restoration of passive joint mobility make further operation practicable It is probably best to limit such procedures to young patients where the prospects of improving passive joint range are good

3 If unsuitable for tenolysis or further tendon repair the affected finger even though unable to be actively flexed at the interphalangeal joints, may still be of use to the hand and many patients particularly women will refuse to part with it. Where more than one finger is affected the importance of retaining even stiff fingers increases

4 Amputation will usually be advised for single finger injuries where failed tendon repair offers no further prospects of improvement and the stiff finger embarrasses the function of the hand Most working patients will request it after a short period of trial even if they reject the advice initially

SOME SPECIAL FEATURES OF SECONDARY MANAGEMENT OF TENDON INJURY

Some attention must now be given to certain special technical or regional problems

Flexor Tendon Grafting[1]

Incisions and Exposure of the Operating Field—The advantages of raising a flap and so *isolating any area of deep repair from the regions of superficial* closure are well known Application of this principle to a finger to give a sufficiently radical exposure of the flexor tendon system and to permit of atraumatic and precise manœuvres conducive to success with the flexor tendon grafting operation is not so generally appreciated A skin and fat flap based on one side of the finger can be raised with safety provided the proper care of design handling and after treatment are applied (Fig. 137) This gives a far better access to the flexor system in the finger than does either a lateral or antero-lateral incision and retraction It permits of full appreciation of the local conditions, precise removal of tendon remnants, proper resection of flexor sheath and fixing of the distal junction of the graft. It should be noted that the *main line of incision is along the neutral line* on the side of the finger—a line which joins the extreme side limits of the transverse interphalangeal creases when the finger is flexed The distal limit of the flap is sufficiently beyond the distal interphalangeal crease to permit of clear exposure of the insertion of the profundus tendon

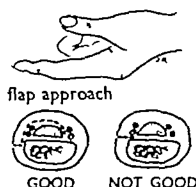


Fig. 137

The incision used in turning back a flap on the finger for the exposure necessary for a free tendon graft
Note the relation to the neuro-vascular bundles. The commonly used lateral incision which gives a much inferior exposure is also indicated for comparison.

[1] Rank, B. K. & Wakefield, A R (1952). *Brit J plast Surg* 4 224

The proximal limit of the flap varies in the case of the index and little fingers from that in the case of the middle and ring fingers. The little and index fingers most commonly suffer flexor tendon injuries and fortunately in these fingers the lateral incision can be carried proximally on the lateral margins of the palm to the line of the distal palmar crease and the proximal margin of the flap is made in this line in each case. This gives a good exposure of the proximal end of the digital theca proper resection of which we regard as an important factor in the out come. In the case of the middle and ring fingers the flap should not be prolonged into the palm so that it may be necessary to make a sepa rate small transverse incision in the distal palmar region for access to the proximal region of the digital theca in the case of these two fingers (Fig 138)

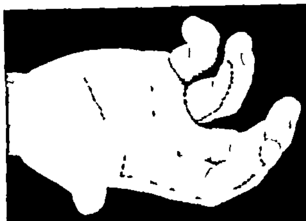


FIG. 138

In the case of index and little fingers—the long flap and a proximal palmar incision gives full access to the region for a tendon graft In the case of the middle and ring fingers the flap does not extend on to the palm and an extra incision is therefore required in the distal palm.

The lateral margin of the flap is behind the digital nerve. The flap is cut thin at this edge so that it is actually raised anterior to the digital nerve after which it is made to include all the tissue bulk in front of the digital theca

The other necessary incisions include (1) a transverse incision in the proximal palm to expose the flexor systems at the region of origin of the lumbrical muscle (2) a long vertical incision proximal to the wrist for exposure and careful removal of the palmaris longus tendon which we favour as donor source for the graft whenever it is present In the case of the thumb flexor only the digital flap and wrist incision are generally required

Radical Resection of the Flexor Digital Sheath and Clearing of Damaged Tendons —We have found that results of flexor tendon grafts have been best when as much as possible of the flexor sheath has been cleanly resected This especially applies to any area of damage and to the thick proximal portion of the digital theca which extends into the distal palm. It is our practice to leave only two bands of sheath one over each of the proximal two phalanges to prevent anterior prolapse of the graft (Fig 139 A) Should these correspond to a region of damage, as the proximal loop frequently does—even this is resected and a retaining loop reconstructed by a piece of the donor tendon complete with its paratenon This is looped around the phalanx or else sutured to each side of it If the second loop cannot be retained no counterpart for this is generally made. It seems that if the proximal retaining loop is too far distal on the first phalanx some degree of prolapse of the graft across the metacarpo-phalangeal joint occurs during flexion This detracts from the full range of movement and the loop is best sited, therefore, towards the base of

lies in a preliminary complete excision of the adherent tendons, followed later by a free tendon graft if and when scar resolution and restoration of passive joint mobility make further operation practicable It is probably best to limit such procedures to young patients where the prospects of improving passive joint range are good

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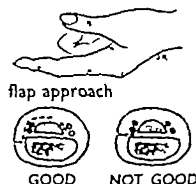


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the finger The removal of the tendon remnants can be difficult at the base of the finger and in the metacarpo-phalangeal region It should be done carefully and under vision even though this means additional incisions for adequate exposure Blind and forceful stripping of adherent tendons and the use of special instruments for the purpose can do much harm to their surroundings and is usually incomplete

Great care should be taken in the removal of the tendons from the front

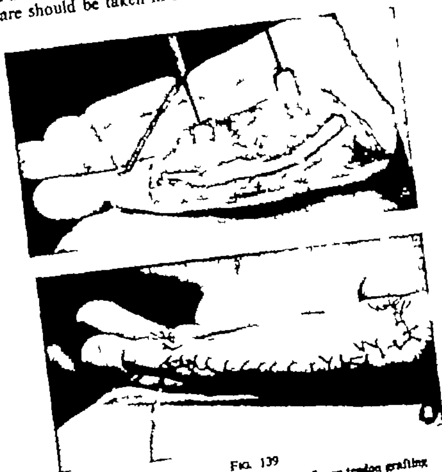


FIG. 139

Successive stages in the operation of free flexor tendon grafting

A. The free graft placed in position and sutured to the terminal profundus tendon stump after resection of the damaged tendons and most of the tendon sheath. Note the two pulleys retained to prevent prolapse of the graft.

B, The flap sutured back before proceeding to the proximal graft junction.

of the proximal interphalangeal joint and in particular where the slips of insertion of the sublimis tendon cross the joint capsule Too radical a dissection in this region may damage the volar plate of the joint unnecessarily This, if combined with too radical a resection of the side attachments of the tendon sheath and the fibres of insertion of the sublimis tendon may result in the distressing " recurvatum " deformity which is associated with many of the disappointing results of flexor tendon grafts

The Choice of the Graft.—Of the many potential donor tendons for this operation we strongly favour the palmaris longus tendon.[1] It best satisfies two main considerations. It has a thin cross-section and so survives more easily as a live graft and, of even more importance, it can be easily removed and transferred complete with its well-developed paratenon.

The extensor longus tendon to the second toe is regarded as a second donor choice in the easily and clinically demonstrable absence of the palmaris longus. A long incision on the foot involves longer recumbency and hospitalisation. The plantaris tendon is conveniently long and thin, but there is no means of predetermining its presence, nor has it such a well-developed paratenon arrangement. The flexor digitorum sublimis tendons have no paratenon and in adults are generally too thick. Our best results using a sublimis tendon are not to be compared with those where the palmaris longus tendon has been used as the graft. To choose deliberately some other donor tendon when the palmaris is present is not only illogical from the point of view of convenience, but ignores the important principles which are fundamental to the success of the procedure.



FIG. 140

The removal of the palmaris longus tendon with its surrounding paratenon

One of the end sutures of the graft is inserted before it is removed to facilitate handling. It is important to keep the graft and its paratenon covered to prevent desiccation. This occurs very quickly under a theatre light.

The Importance of Paratenon.—The most mobile grafts are those transferred with an intact paratenon. The degree of excursion of a palmaris tendon graft through its paratenon can be well demonstrated when the graft is in place. The paratenon rapidly adheres to its surroundings. In the absence of paratenon a tendon graft becomes adherent to surrounding soft tissues and can only act by pulling on them. Because of the importance of paratenon to success the donor tendon must never be stripped or dragged out through a small incision. The necessity for a long forearm incision is obvious (Fig. 140).

Furthermore it is important to see that the paratenon is not drawn concertina-fashion to one end of the graft when it is inserted in its new site. *The paratenon should be carefully drawn sleeve-like to the proximal junction and over the distal interphalangeal joint.* Adhesions at these points will

[1] In a clinical survey of 1,000 hospital patients, including 500 males and 500 females, the following observations were made concerning the palmaris longus tendon.—

Males.—The tendon was present on both sides in 69·6 per cent.; on the right side only in 6·8 per cent.; on the left side only in 7 per cent. Both tendons were absent in 16·6 per cent.

Females.—The tendon was present on both sides in 71·2 per cent.; on the right side only in 7·4 per cent.; on the left side only in 6·2 per cent. Both tendons were absent in 15·2 per cent.

otherwise abort the through pull of the graft for a tendon expends its traction effect at its most proximal point of fixation or insertion

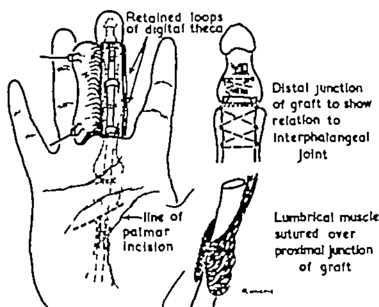


Fig. 141

The placing of the graft and the siting of the proximal and distal graft junctions.

Of recent years some doubt has been thrown on the importance of paratenon in relation to this procedure, and many excellent results have been obtained by surgeons who retain only the visceral layer of the paratenon. Although it would seem not to be as important to success as was previously believed it is nevertheless a fact that most of our best and quickest results have been obtained using the method described. For the time being therefore an open mind should be kept on this matter until more evidence is available to determine whether an abundance of paratenon on the graft is in fact beneficial of no particular value or even perhaps in some cases detrimental



Fig. 142

The effect of placing the distal graft junction too far proximally

This was an early case of flexor tendon graft where a longer stump of the profundus tendon was left and where adhesion at the terminal suture point prevented independent flexion at the end joint



Fig 143

The method of fixing the distal end of the tendon graft to bone

For this purpose a wire stitch is used which transfixes the terminal phalanx and is tied subcutaneously on the dorsum through a separate incision. This procedure is used only where no stump of the profundus tendon can be retained.

The Junctions of the Graft—(1) *The Distal Anastomosis* —We have found it most simple and effective to fix the graft to a very short stump of profundus tendon at a point just distal to the distal interphalangeal joint (Fig. 141)

If a longer stump of profundus tendon is left, the adhesion point is proximal to this joint so that its independent active flexion is lost (Fig. 142)

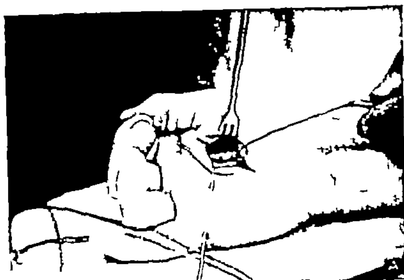




FIG 144

The use of the lumbrical muscle to overlap the proximal graft junction
A, Shows the proximal tendon suture completed.
B The suture point in the tendon is buried in the fleshy belly of the lumbrical muscle, which is sutured around it.

If this point is appreciated it is unnecessary to go to the extreme of attaching the graft directly to bone (Fig. 143) This raises unnecessary extra technical difficulties and causes undesirable added trauma to the region of the distal interphalangeal joint There are definite hazards to transfixion of the distal phalanx in the very limited space between joint structures and nail bed

(2) *The Proximal Anastomosis* —This should be deep in the palm close to the site of origin of the lumbrical muscle By suturing this small muscle

around the graft junction the only adhesion at this point is to a mobile structure (Fig. 144) It is a common mistake for the proximal junction of the graft to be sited too far distally in the palm where it is liable to adhesion to skin or other relatively rigid structures This renders the whole purpose of the operation void





FIG. 145

The method of fixing the finger in exaggerated flexion while the proximal suture of the tendon graft is completed.

The Tension of the Graft —The object is to restore the finger to its normal posture when a graft is finally sutured in place. This means in a degree of flexion which increases from the index to the little finger Moreover the finger should maintain its normal posture change and relationship to neighbouring fingers as the wrist is passively flexed or extended To achieve this it is our practice having fixed the distal end of the graft and closed the finger incision to keep the finger in an exaggerated degree of flexion (Fig. 145) while carrying

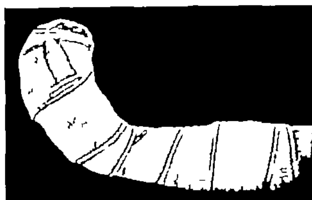


FIG. 146

The final position in which hand and fingers are immobilised following flexor tendon repair

The fingers are fixed in the position of rest, and additional tendon relaxation is then obtained by increasing wrist flexion.



FIG. 147

Result of secondary flexor tendon graft to the little finger

Both tendons had been divided over the proximal phalanx. Primary treatment consisted only of careful skin suture.

out the proximal anastomosis in the palm wound aided by a traction suture in the profundus tendon The anastomosis can then be done without slack and without strain Release of the exaggerated finger posture then usually leaves the finger in normal posture and tension as can be both seen and felt It is better to have the graft too tense than too slack Finesse in this manœuvre

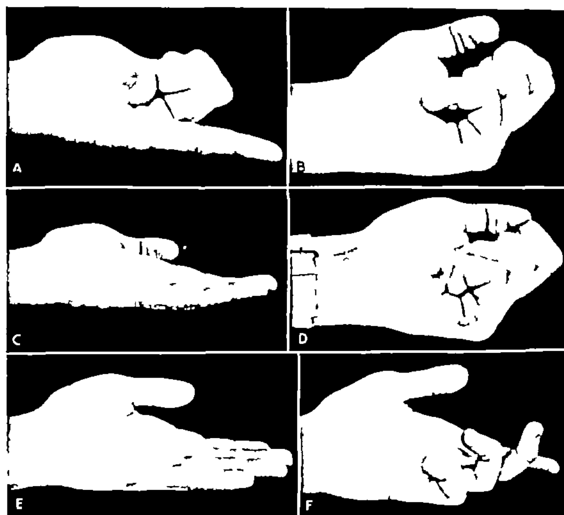


Fig 148

Result of secondary flexor tendon graft at different stages after operation

A, Prior to operation. Both tendons had been cut over the proximal phalanx and only the skin repaired primarily

B, C The range of movement six weeks after tendon graft.

D E, F The final result eight months later

which is by far the most tedious and difficult of the whole procedure can only be developed by experience

The Post-operative ... post-operative care of tendon grafts differs in no ... direct repair of tendons. The principles ... in Chapter VII

The Use of Tendon Substitutes

For some years the possibility of artificial substitutes for damaged tendons under circumstances where the results of tendon repair or graft are still unsatisfactory has been under consideration by many centres. The absence of adhesion to the surroundings along the length of the material used makes the method appear attractive, but that same lack of union with the surroundings makes the problem of end attachments more difficult. The search for a suitable inert malleable, strong, unstretchable and durable substitute, together with a method of stable end union continues.

At present it is our firm view however that despite its shortcomings, free flexor tendon grafting is the method of choice if favourable indications for grafting exist. Having regard to the long history of artificial substitutes for various tissues in the body and the train of complications they introduce, it is unlikely that tendon substitutes will ever replace autogenous tendon grafts as first choice in favourable cases

So far we have only considered the use of foreign materials as an experiment in a few cases where other method of orthodox tendon repair have failed or seemed certain to fail

Despite some initial success the ultimate results in all cases have been disappointing for a wide variety of reasons including delayed sepsis breakage of the material used tearing out of the end attachment and failure to establish active movement despite continuity of the prosthesis

No doubt many modifications both in material and technique will be made in time, but for the present it seems best to regard such procedures as experimental for cases unsuited for standard methods of tendon repair

Tenodesis for Terminal Joint Stability

The indications for this procedure have already been discussed (p 180) Its main advantage over arthrodesis of the terminal interphalangeal joint is that the period of incapacity is shorter and the patient is able to return to work sooner The technique has been described by Spak[1] and we have followed his method with only minor variations in detail The main difference in the technique that we have used has been that the wire suture anchoring the tendon to the middle phalanx has been a buried one rather than the removable one as preferred by Spak

To be effective a sufficient length of stump of the flexor digitorum profundus must be present and it is not practicable in cases where the original tendon injury was close to its insertion

The operation area is exposed by turning back the usual type of flap (Fig. 149) but this need only be raised over the distal half of the finger and it is important not to encroach on the region of the proximal interphalangeal joint and the intact sublimis tendon. A small area of bone is gouged out of

[1] Spak Ivar (1955-56) Tenodesis of the *distal finger joint*—a method of repair for loss of the flexor profundus function *Acta chir scand* 110 4

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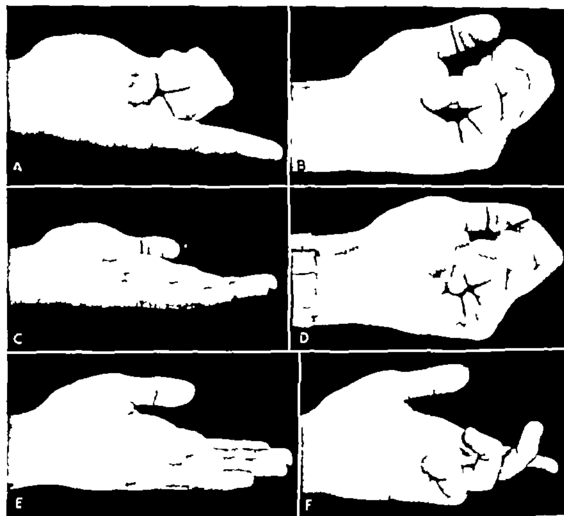


FIG. 148

Result of secondary flexor tendon graft at different stages after operation

A Prior to operation Both tendons had been cut over the proximal phalanx and only the skin repaired primarily

B, C The range of movement six weeks after tendon graft.

D E, F The final result eight months later

which is by far the most tedious and difficult of the whole procedure can only be developed by experience.

The Post-operative Management —The post-operative care of tendon grafts differs in no way from that required for direct repair of tendons The principles concerned have already been set out in Chapter VII

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[1] Spak Ivar (1955-56) Tenodesis of the distal finger joint—a method of repair for loss o flexor profundus function. *Acta chir scand* 110 4

the front of the distal half of the middle phalanx and two fine holes are drilled from the bottom of this depression through to the dorsum where the bone is exposed through a longitudinal incision The length of the profundus stump is adjusted to produce a fixed joint flexion of approximately 30 degrees when it is fitted into the bone A double threaded wire suture is then inserted in the tendon by the Bunnell technique (p 119) and tied over the back of the phalanx after threading the two ends through the drill holes.



Fig 149

The method of fixing the distal interphalangeal joint by tenodesis and temporary pin transfixion

A, A wire suture through the stump of the profundus tendon is passed through drill holes in the middle phalanx.

B The stump of tendon is pulled into a shallow pit gouged out of the phalanx and the wire ends tied on the dorsum.

C X-ray shows the pin which ... the position until the ... becomes ... fective

The tenodesis is then g... by drilling a ... er wire obliquely from the back of the ... across the joint into the distal phalanx ... The end of ... off short but not too short for ... and the ... over it on th... No other ... d and ... resume work ... wounds ... wire ... for ... is ... then ...

EXTENSOR TENDONS

The Mallet Finger.—This deformity may result from two classes of injury —

1 Open cutting injuries where the section of the tendon over the joint has not been noticed and the wound has been sutured or else has healed spontaneously The same result may follow when the cut tendon has in fact been sutured but immobilisation has been abandoned too soon. This type of mistake happens when there is discontinuity of personal care and someone unaware or forgetful of the sutured tendon removes the skin sutures and sends the patient on his way

2. Closed injuries resulting from sudden forced flexion of the distal joint against extensor resistance. The housewife who was turning the mattress, the footballer who misjudges his mark so that the ball strikes the end of his finger as he is reaching for it or the wicket keeper hit on the finger tip as he opens his hand—these are typical stories Closed injuries do not produce a clean division of the tendon. There is usually a subcutaneous tearing of the extensor expansion near its insertion Less commonly there is an avulsion of the tendon insertion with a small flake or chip of bone including part of the articular surface (Fig. 29) The diagnosis is often uncertain at the time of injury on account of swelling and pain and most of these cases therefore present for secondary treatment of an established mallet finger deformity

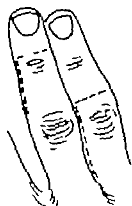


FIG. 150

The incisions used for raising flaps to expose the extensor expansion over the proximal and distal interphalangeal joints.

Both management and prognosis differ considerably in these two classes of injury

In the first type (*i.e* mallet finger after open injury) direct repair of the cut tendon is nearly always possible if a long period of time has not elapsed since the injury The tendon is approached by an angle incision raising a triangular flap (Fig 150) An avascular field is essential for precision in identification dissection and repair For this purpose a broad rubber band about the base of the finger tightened and held with a clip is effective The proximal tendon end is freed from adhesion to the middle phalanx drawn distally and sutured to the distal end, which has been also freed and trimmed One or two side-on mattress sutures are generally used for this purpose (Fig. 151) The finger and hand are then immobilised in the position of function except that the distal interphalangeal joint of the affected finger is hyperextended It is convenient to do this by making the plaster in two stages—first a small volar plaster setting the correct posture of the finger and subsequently a separate plaster relating to hand and wrist posture We regard the common practice of using only a local finger plaster of a thimble type as *inadequate* fixation and have seen ample evidence of the risks of their local pressure effects.

Results of direct repair in most of these cases are good (Fig. 152)

In the second type (*i e* mallet finger after closed injury) decisions are more difficult and the prognosis more erratic If conservative management is adopted even at an early stage and with prolonged fixation of the distal joint in the extended position, a feat not easy to obtain with absolute continuity there is unlikely to be accurate apposition of the frayed tendon ends. Natural union does not occur without scar separation and at least some order of the disability will persist If operation is undertaken the frayed tendon ends separated by new scar and reaction are difficult to identify and repair without trimming and shortening End to-end apposition is thus impossible without straining the position of extension Moreover this has to be accomplished in a region devoid of protective soft tissue insulation from joint cavity on the one side and skin surface on the other Even if improved posture and some extensor function result from such operations, full flexion is unlikely to be regained on account of tendon foreshortening necessitated by the trimming Either line of management is time-consuming for the patient necessitating disuse of the hand for a period approximating six weeks



FIG 151

Suturing the extensor tendon

The region is exposed indirectly by a flap Side-on mattress sutures are used so that silk is not exposed to the joint. Two stitches are generally used The method of suturing a flat tendon is not the same as for a round tendon.

What is to be done for the best? The literature is full of unproven ideas and suggestions and there are many gadgets described for immobilising a finger in the difficult position suggested On the contrary it is notably void of any critical review of long term results by any particular method of treatment with one important exception A recent Swedish paper by Backdahl[1] records a long term review not only of cases treated conservatively and by operation but of cases left untreated He makes the important general observation that many of these cases which are left untreated have only partial disability They gain some limited return of extensor function so that their long term disability more often than not is minimal and most patients rapidly accustom themselves to this Continued disability and nuisance are usually confined to mallet fingers of gross degree with no extension whatever or where there is persistent pain and tenderness about the joint. This is usually due to arthritis following avulsion of the tendon insertion with associated chip fracture when the bony fragment is generally displaced into the joint This condition can be ascertained by X ray examination

On the basis of these observations together with the technical difficulties, the time loss and the erratic results of operation we have recently modified our views on this subject When faced with a mallet finger deformity which

[1] Backdahl, M (1956). Ruptures of the extensor aponeurosis at the distal digital joints. *Acta chir scand* 3 2.

has not been due to a recently incised wound, we now advocate operation only under the following conditions —

1 If there is a chip fracture. It follows that all cases of mallet finger deformity should be X rayed Operation should be undertaken in these cases at least to remove the bone fragment If reaffixing of the tendon is impracticable as it generally is, the joint can be fused in moderate flexion (about 30 degrees) Fusion is achieved by excision of articular cartilage and pin transfixion (Fig. 164) The pin may be cut short and left *in situ*

2. Where the extension disability is complete and where the order of deformity is a nuisance repair is also attempted The scar between the tendon ends is divided and resutured

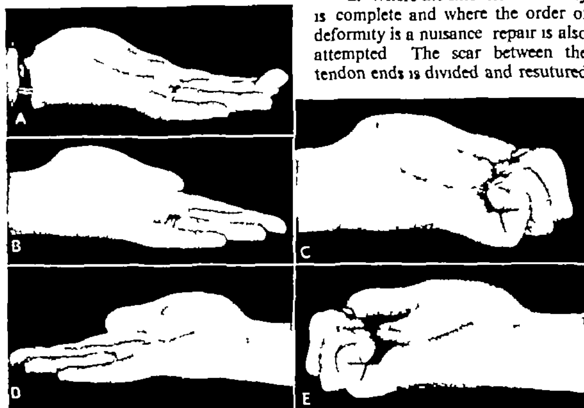


Fig. 152

Secondary repair of extensor expansion divided over the distal interphalangeal joint

A Shows the typical mallet finger deformity of the middle finger

B C, The result of secondary direct repair of the extensor expansion.

D E, Show range of movement in the normal hand for comparison.

with sufficient overlap to retain full extension Some improvement in joint posture and control is usually obtained but full extension is rarely restored

3 Certain cosmetic or occupational indications might occasionally justify operation when there is no improvement over a period even if the loss of extensor function is incomplete

We see no place for conservative immobilisation where these indications exist At operation if repair is found to be impracticable, joint fusion can be undertaken

Outside of these indications come the large majority of mallet finger

deformities where the extension limitation is only in the last 30 to 40 degrees of movement Many of these represent incomplete disruptions of the extensor tendon or else scar union and its subsequent contraction which gives some

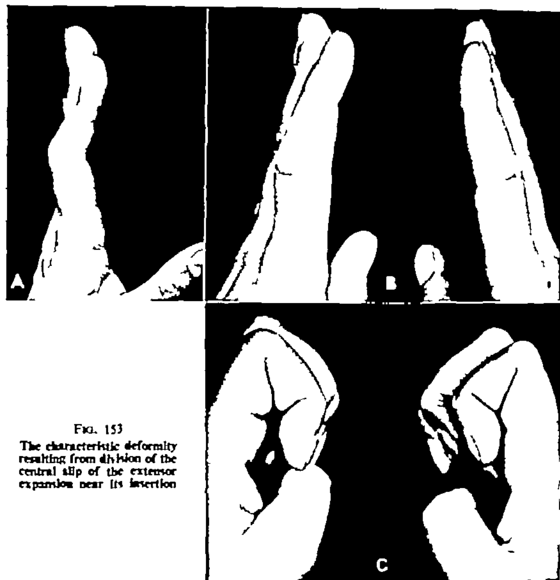


Fig. 153
The characteristic deformity resulting from division of the central slip of the extensor expansion near its insertion

A Prior to operation. B C, The range of finger movement compared with the opposite hand after dividing the two lateral slips of the extensor expansion and resuturing each to that of the opposite side beyond the joint. A cruciate tendon arrangement is thus produced over the back of the joint.

return of extensor function In all these cases after a few months the inconvenience is negligible and forgotten

This discriminating policy of operating only on mallet finger deformities in particular circumstances saves much unnecessary treatment reveals many surprises on account of spontaneous improvement and saves much time loss while over all the standard of results is certainly no worse than that of elective treatment of one sort or another for all cases.

The Cut Central Slip of the Extensor Expansion —Because of the insidious

onset of deformity this is one of the commonest extensor tendon injuries which present for secondary treatment It usually presents as an established deformity after an open injury where the cut tendon has been missed but we do occasionally see it as a closed injury The central slip is damaged close to its insertion and by the time the flexion deformity is established it is often technically impossible to repair it successfully Where secondary joint changes have not yet occurred and the proximal interphalangeal joint can still be passively straightened it is possible, after extensive dissection and mobilisation to bring the two lateral slips of the expansion into the midline across the back of the joint In this position they are sutured together to prevent recurrence of their lateral slide Sometimes they are divided and each slip resutured to that of the opposite side in a cruciate arrangement (Fig 153) Occasionally where one lateral slip has been divided as well as the central element it can be looped around the slip of the opposite side and resutured to itself so forming a loop which retains the one intact portion of the tendon over the back of the joint There are many possible variations in this type of repair but all are designed to allow the intact lateral slips to extend their pull across the joint dorsal to the axis of the finger and so take over the function of extending the proximal as well as the distal joint

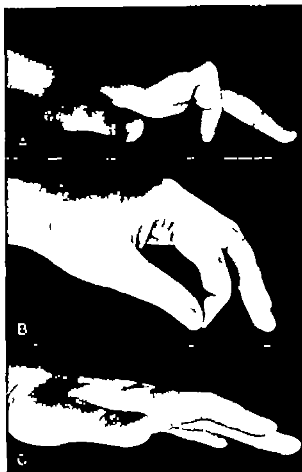


FIG 154

Long-standing deformity resulting from division of the central slip of the extensor expansion—treated by arthrodesis of the proximal interphalangeal joint.

Where secondary joint changes are advanced or operation has failed it is best to arthrodese the proximal joint in partial flexion (Fig. 154) Such an arthrodesis is of special value in burns of the dorsum where the central slip has sloughed and left the joint open for a period

The Severed Extensor Pollicis Longus—Secondary repair of this tendon over the interphalangeal joint differs in no way from similar injuries in the finger There is little retraction of the cut end and direct repair is usually possible within a reasonable period of time.

When the injury is proximal to the metacarpo-phalangeal joint retraction and contraction of the proximal end occur rapidly If repair is carried out within a few weeks it may still be possible to approximate the two ends without undue tension particularly if the tendon is lifted out of its tunnel

deformities where the extension limitation is only in the last 30 to 40 degrees of movement Many of these represent incomplete disruptions of the extensor tendon or else scar union and its subsequent contraction which gives some

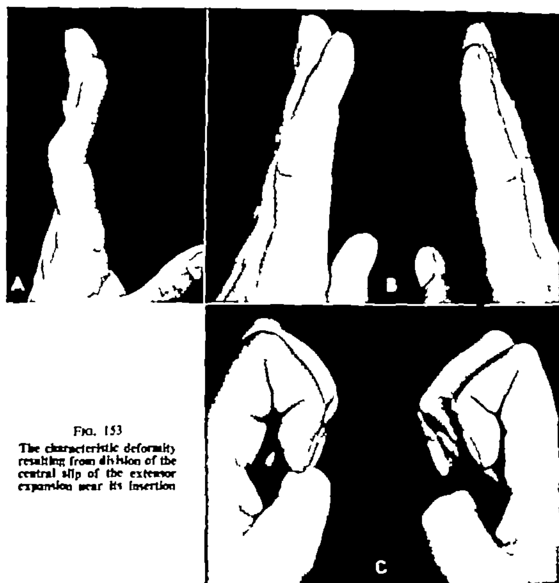


FIG. 153

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A, Prior to operation. B C The range of finger movement compared with the opposite hand after dividing the two lateral slips of the extensor expansion and resuturing each to that of the opposite side beyond the joint. A cruciate tendon arrangement is thus produced over the back of the joint.

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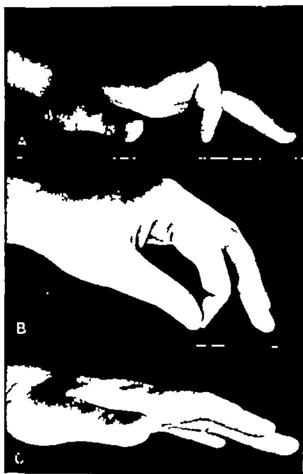


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When the injury is proximal to the metacarpo-phalangeal joint retraction and contraction of the proximal end occur rapidly If repair is carried out within a few weeks it may still be possible to approximate the two ends without undue tension, particularly if the tendon is *lifted out of its tunnel*

and allowed to pursue a straight course (Fig. 155) Frequently however this is not possible, and either a free graft or a tendon transplant must be carried out A transplant is preferable and the common extensor tendon to the index finger is easily the best choice (Fig. 156) This tendon will not reach as far as the metacarpo-phalangeal joint of the thumb and can only

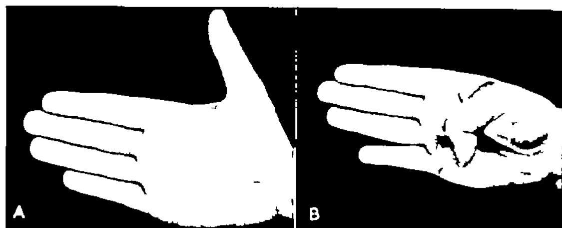


FIG 155
Secondary direct repair of the extensor pollicis longus
A and B show the range of movement following operation.

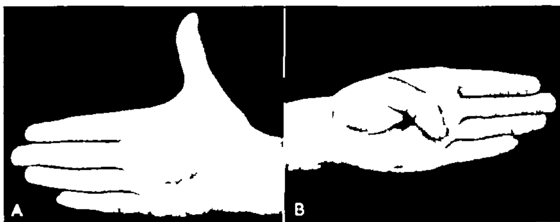


FIG 156
Secondary tendon transplant to the extensor pollicis longus using the *extensor digitorum communis tendon to the index finger*
A, Maximum extension. B, Maximum flexion. The time lapse and degree of retraction of the proximal end of the extensor pollicis longus were such that direct repair of that tendon was impossible.

be used when tendon section is proximal to this. The use of one of the radial wrist extensors when the point of section is close to the insertion of these muscles is ill advised The normal excursion and direction of pull of these muscles are unsatisfactory for the purpose and the results following their use are poor by comparison

When the injury is at or near the metacarpo-phalangeal joint and direct tendon suture is not possible a section of free tendon graft from

the palmaris longus or other suitable tendon must be used to bridge the gap (Fig. 157) There is no available tendon of sufficient length for transplant to this region

The Severed Finger Extensor on the Hand—Here secondary repair of extensor tendons can be achieved in many ways and in different combinations If there is no tendon loss and retraction can easily be overcome, direct repair is a simple procedure. Otherwise, the simple solution in single finger injuries is to anchor the distal cut end to the intact tendon of a neighbouring

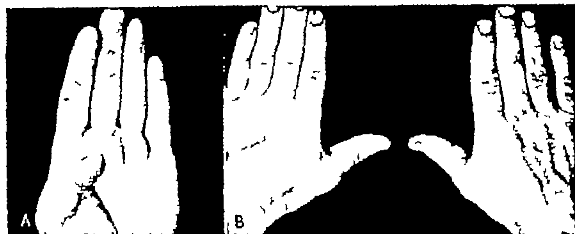


FIG. 157

Secondary free tendon graft to the right extensor pollicis longus

A, The thumb in flexion. B, Maximum extension. The degree of tendon loss after excision of the scarred and damaged section of tendon did not permit a direct repair and the site of section (over the metacarpo-phalangeal joint) was too far distal for transplant.

finger If the adjacent finger has two tendon slips, one of these can be transplanted to the affected finger There are many ways of rearranging the extensor tendons on the back of the hand to provide a functioning unit to each digit and surgical opportunism is the keynote of secondary exploration in such injuries.

Where all tendons are damaged, with loss of substance, free grafts to each finger are necessary and we have seen how this must often be preceded by the provision of an adequate soft tissue cover for the area (Fig. 158)

Combined Flexor and Extensor Injuries—Occasionally both flexor and extensor tendons to a finger are cut simultaneously particularly in the index finger (Fig. 129). Often the intervening bone or joint will also have been damaged and where such a finger has been retained primarily subsequent joint stiffness will usually preclude any attempt at tendon restoration

If the injury is confined to tendons or minimal joint damage responds well to intermediate treatment the surgeon is faced with the problem of which tendon to repair first or whether to operate on both simultaneously The latter possibility is quickly eliminated for while finger posture is that of the position of rest in both cases after operation we rely on exaggerated wrist posture for tendon relaxation and the neutral position is not sufficient for this purpose

Whichever tendon is repaired first it will be necessary to rely on splints to provide antagonistic action until the second tendon can be dealt with. There

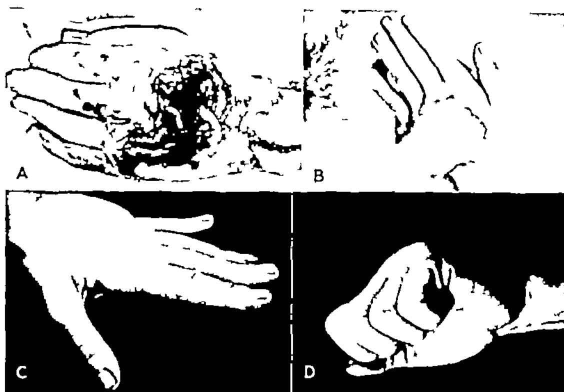


Fig 158

Secondary extensor tendon repair preceded by soft tissue replacement over the dorsum of the hand

A, The injury showing skin loss and tendon damage The extensor tendons to index and middle fingers were divided and there was loss of substance of the index extensors. There was also a fracture of the third metacarpal running into the metacarpo-phalangeal joint which was laid open. B, Primary direct abdominal flap after closure of the metacarpo-phalangeal joint and direct repair of the extensor tendon to middle finger C, D The end result eight months after secondary free tendon graft to the extensor communis of the index finger

are arguments both ways but we would prefer to operate first on the extensor tendon—the simpler procedure more likely to provide a quick return of active movement.

NERVES

As in the case of tendons secondary treatment of major nerve injuries may be required for recently healed tidy injuries where for some reason primary repair has not been undertaken or for untidy" injuries after intermediate treatment has prepared the hand for operative nerve repair

A case may have been managed throughout by the same surgeon who has observed the nerve injury at the initial operation and knows precisely the state of affairs which will be encountered On the other hand the surgeon responsible for the reparative work may frequently have little or no information to guide him As often as not the affected nerve has not even been seen at the primary operation

In many simple injuries the divided nerve ends may be close together or the nerve may be incompletely divided and in such cases expectant treatment will be followed by some degree of nerve recovery Nevertheless, we are very strongly of the opinion that all cases of open injury which are followed by clinical evidence of nerve damage should be explored as soon as practicable after sound healing if the local state of affairs is not precisely known In severe untidy injuries often with tissue loss the necessity for exploration is even more obvious, but must often be delayed until skin loss has been made good sepsis eliminated and joint mobility restored In the first case the exploration may be carried out within a few weeks of the injury in the second it may be delayed for several months.

In any case every effort should be made to render the hand fit for such exploration within three months of the primary injury and earlier if possible Delay beyond such period has repeatedly been shown to prejudice the chances of successful nerve repair

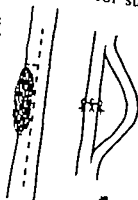


FIG 159
Method of repairing portion of a main nerve trunk leaving the undamaged portion intact

At secondary nerve exploration one of a number of conditions may be found Operation must not be approached with predetermined fixed plans of procedure Much will depend on the findings

1 **The nerve ends may be readily found within a short distance of each other but without continuity** This is the common state of affairs after incised wounds, and simple approximation of the two ends can be carried out after excision of the end bulbs

2. **The nerve ends may appear to be in continuity, with a large fusiform swelling at the site of injury** It is in these cases that management is controversial and where considerable experience and judgment are required If the exploration is an early one and the continuity seems good with a small short neuroma they may be left undisturbed for a trial period which should not exceed six months If there is then no evidence of progressive clinical recovery a further exploration should be carried out with resection of the scarred portion of the nerve and end-to-end perineural suture Where exploration has of necessity been delayed for many months without any sign of clinical recovery then it will generally be decided to resect the neuroma and anastomose the two ends.

3 **Portion of the diameter of the nerve may be in continuity and apparently undamaged, but the rest of the nerve obviously divided and the ends joined by a bulbous scar** This picture can often be anticipated by the clinical signs It will usually be possible by gently stripping upwards and downwards to separate the damaged from the undamaged portions of the nerve over a distance of a few centimetres The ends of the damaged part can then be approximated after excision of the intervening scar leaving the intact section of the nerve in a loop (Fig 159)

4 **The ends of the nerve may be found widely separated and only able to be brought together after extensive mobilisation or transposition and exaggerated**

joint postures This has its main application in relation to the ulnar nerve where the standard method of transposition in front of the elbow adds considerably to the length of nerve available for repair This procedure, combined with flexion of the elbow joint, will allow most ulnar nerve lesions to be repaired despite the loss of a substantial amount of nerve substance In the case of the median nerve the amount to be gained by extensive mobilisation of the nerve by altering the joint positions is strictly limited as the course of the nerve from its origin to its terminal branches is almost straight, and is already on the flexor surface the whole way Sometimes where both major nerves are involved shortening of the forearm bones to a limited degree may add a little further to the available nerve length for repair This may be particularly applicable where both forearm bones have already been fractured in the original injury and where in some cases non union or mal union has also to be treated as well as the nerve injury

5 **The ends of the nerve may be found to be widely separated, and it is impossible to approximate them after scar excision by ordinary methods of mobilisation and posture** These are the cases which have been complicated at the initial injury by extensive soft tissue loss which includes portion of the length of the nerve Nerve grafting offers the only prospect of restoring continuity Where this state of affairs exists in the palm and the nerves involved are the common digital branches of the median and ulnar nerves, which at this point are essentially sensory in type, nerve grafts to bridge such gaps are well worth while. Pieces of cutaneous sensory nerve can be used of approximately the same diameter or the digital nerve up one side of the finger may be used as a graft to restore sensation up the other side thus ensuring that each finger has at least one functioning nerve (Fig. 160) It is common for such problems to arise in the more severe hand injuries involving associated bone, tendon and joint damage Sometimes in considering the plan for secondary repair one or more grossly damaged fingers may be removed with advantage and may form the source of supply not only for skin but for nerve grafting.

Where the main nerve trunks of the median and ulnar nerves are involved proximal to the wrist cable grafts of sections of cutaneous nerves can be employed to bridge the gap and some degree of sensory recovery can often be achieved thereby It must be remembered that these are usually gross injuries where even a small degree of success may provide some value to an otherwise useless hand

Irreparable Nerve Injuries and Failed Nerve Repairs

Despite meticulous surgery and ingenious methods of nerve anastomosis or grafting a certain proportion of nerve injuries be irreparable Others will fail to regenerate satisfactori [illegible] lems then concern either sensory and or motor

Median Nerve Only —Loss [illegible] e distribution is one of the worst handicaps a

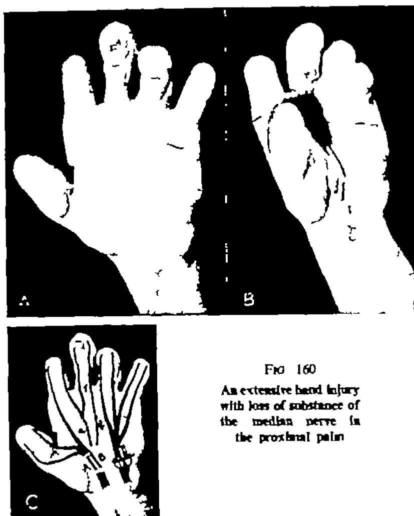


FIG 160

An extensive hand injury with loss of substance of the median nerve in the proximal palm

This injury inflicted by a power saw was treated primarily by amputation of all four fingers through the middle phalanges, by direct suture of a transverse wound on the front of the carpus which involved the median and ulnar nerves and some of the superficial flexor tendons, and by attachment of a direct abdominal flap over the thenar eminence and side of the thumb where there was extensive soft tissue loss. The abdominal flap was detached after three weeks. Three months later secondary exploration of the wound at the base of the palm was undertaken. At this time there were clinically complete median and ulnar nerve lesions. The sensory and motor branches of the ulnar nerve just beyond its bifurcation were found to be divided, and these two branches were sutured separately The median nerve was found divided just proximal to its subdivision into terminal branches. There was loss of substance of the nerve to the extent of about one and a half inches after preparation of the nerve ends Two segments of free nerve graft taken from the common digital nerves to the adjacent sides of index and middle, and middle and ring fingers were used to bridge the gap in an effort to obtain some sensory return to the thumb and index finger stumps. Four months later anticipating that there would be no motor recovery in the median nerve, the remnant of the flexor digitorum sublimis tendon to ring finger was withdrawn above the wrist and to this tendon was attached a free graft of palmaris longus which was passed around the tendon of the flexor carpi ulnaris, across the front of the wrist and base of the thenar eminence, and sutured to the periosteum of the first metacarpal in the region of the insertion of the opponens pollicis. The purpose of this was to provide some degree of opposition of the thumb metacarpal.

A, B, Show the hand two years after the completion of this programme. There has been full sensory recovery on the thumb radial side of index, and on ring and little finger stumps. There is no sensation in the middle finger stump, as was to be expected. There has been good motor recovery of the ulnar nerve in relation to the hypothenar muscles, interossei, and adductor pollicis. A reasonable degree of thumb opposition is provided by the combined actions of the flexor pollicis longus, adductor pollicis, and the transplanted tendon described above The latter can be seen contracting as it passes across the front of the wrist and base of the thumb. It should be noted that in this case the order of sensory return to the radial side of the ring finger indicated that this area was supplied by the ulnar nerve and not, as is normally the case by the median. This has been indicated in the diagram.

Joint postures This has its main application in relation to the ulnar nerve where the standard method of transposition in front of the elbow adds considerably to the length of nerve available for repair This procedure, combined with flexion of the elbow joint, will allow most ulnar nerve lesions to be repaired despite the loss of a substantial amount of nerve substance. In the case of the median nerve the amount to be gained by extensive mobilisation of the nerve by altering the joint positions is strictly limited, as the course of the nerve from its origin to its terminal branches is almost straight and is already on the flexor surface the whole way Sometimes where both major nerves are involved shortening of the forearm bones to a limited degree may add a little further to the available nerve length for repair This may be particularly applicable where both forearm bones have already been fractured in the original injury and where in some cases non-union or mal union has also to be treated as well as the nerve injury

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Irreparable Nerve Injuries and Failed Nerve Repairs

Despite meticulous surgery and ingenious methods of nerve anastomosis or grafting a certain proportion of nerve injuries will be irreparable. Others will fail to regenerate satisfactorily after repair The problems then concern either sensory and or motor loss in one or both major nerves

Median Nerve Only—Loss of sensation of median nerve distribution is one of the worst handicaps a hand can suffer Almost every use to which

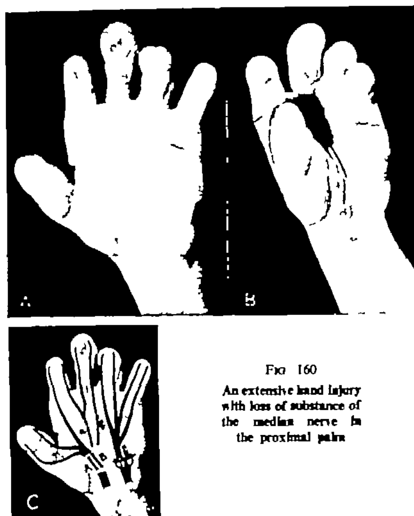


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the hand is normally put is dependent upon discriminatory sensation in this region Not only is function grossly impaired in this way but such hands are prone to petty injuries and burns which are slow to heal Trophic changes and neuralgia of varying grades of severity add to the disability Fortunately a sufficient degree of protective sensory recovery usually follows nerve repair or grafting but this still fails to supply a sufficient discriminatory sense to satisfy the demands of finer movements and specialised occupations In certain selected cases of this type consideration should be given to the transfer of an island flap from the ulnar side of the pulp of the ring finger carried on a neurovascular pedicle and tunnelled across the palm to the thumb pulp The skin of the thumb pulp which it replaces can then be used as a free graft on the site of origin of the flap This type of procedure or any of its modifications can add greatly to the functional value of such a hand [1]



FIG 161

A frozen useless hand with irreparable tendon and median nerve injury

This patient, a man of 65 years of age, suffered intractable pain and was relieved by forearm amputation. A decision for primary amputation in this case would have saved much suffering and prolonged treatment.

Occasionally an irreparable median nerve injury is also associated with such extensive scarring and tendon damage that the loss of finger function together with anæsthesia, trophic changes and causalgic pain may call for amputation of a hand which is not only useless, but an embarrassment (Fig. 161)

The degree of motor loss associated with irreparable median nerve damage varies considerably as does the patient s ability to compensate for it In many cases the movement of opposition although incomplete, remains adequate for all ordinary purposes and no tendon transplants are required However when palmar abduction and opposition are inadequate these movements can be assisted by detaching the flexor digitorum sublimis tendon to the ring finger from its insertion withdrawing it at the wrist and then threading it subcutaneously across the front of the wrist and thenar eminence where it is finally sutured to the tendon of insertion of the abductor pollicis brevis Whether or not this tendon is looped around the tendon of the flexor carpi ulnaris before passing to its new insertion seems to matter little

Ulnar Nerve Only —In the case of the ulnar nerve the sensory problems are not so important, as the fingers affected are not so vital to hand function and usually the only finger completely anæsthetic is the little one Furthermore in injuries at the wrist the dorsal branch of the nerve is usually spared and supplies some sensory protection for the ulnar border of the hand and little finger

[1] Moberg, E. & Littler W Personal communication.

The motor loss produces the characteristic ulnar claw hand with hyper extension of the metacarpo-phalangeal joints and flexion of the interphalangeal joints of the ring, little and sometimes the middle finger. Loss of active adduction and abduction of the fingers weakens the hand but is not of great moment in its everyday use. In some cases the deformity is not severe and the joints remain mobile. In such circumstances it is best accepted. If the claw deformity is incapacitating in relation to certain manipulative occupations the posture and function of the affected fingers can sometimes be improved as suggested by Bunnell by detaching the flexor digitorum sublimis tendons from their insertions, withdrawing them through a palmar incision threading them through the lumbrical canals and attaching them to the lateral bands of the extensor hoods. This procedure is especially indicated when the clawing deformity of an ulnar nerve lesion is associated with progressive rigidity in the proximal interphalangeal joint and flexor tendon contracture (Fig 162). This can usually be overcome by continued use of an elastic traction splint but the operation is necessary to provide permanent stability and to prevent further contracture.



FIG 162

Secondary tendon and joint contracture following the prolonged clawing of an ulnar nerve lesion

These changes developed early and persisted despite a reasonable degree of both motor and sensory recovery in the ulnar nerve. Such changes can usually be prevented by the early and continued use of elastic traction splints throughout the period required for nerve regeneration.

Combined Median and Ulnar Nerve Lesions—The greatest problems of unsuccessful nerve repairs in the hand arise when both the major nerves are damaged. Frequently they are only part of a severe compound forearm injury with fracture and muscle damage as well as mangling or avulsion of the nerves—injuries which by their very nature and extent will often involve amputation either primary or delayed. If there is total loss of both median and ulnar nerve sensation despite all efforts at nerve repair or graft, there is no more that can be done from the sensory point of view and a decision has to be made as to whether the limb is to be amputated or retained. In most cases, however a sufficient degree of protective sensation can be restored to the hand by nerve repairs or grafts to warrant its retention.

When the motor function of both nerves is lost in wrist and lower forearm injuries none of the compensatory mechanisms that come into play when only one nerve is damaged are available and the result is a complete claw hand. The most significant element of this deformity is the loss of all power of opposition, and the thumb becomes simply another finger both in posture and function.

Clawing of the fingers can be improved by transposing the flexor digitorum sublimis tendons into the lateral bands of the extensor hoods as described

above However the high incidence of recurvatum deform proximal interphalangeal joints following this procedure is a major dis The four tailed free graft of Paul Brand[1] using the extensor car brevis as the motor unit may prove to be a better operation

To provide opposition for the thumb the sublimis tendon to finger can be spared from the other transplant and transposed acros of the wrist to be inserted into the abductor pollicis brevis tendon as previously in relation to median nerve injuries alone

Although many other different transplants have been devise type of hand the correction of clawing and the provision of an mechanism are the two essentials and these alone will provide a hand in most cases.

As we have limited the scope of this book to hand injuries from injuries which affect the hand we are little concerned with ra damage or high median or ulnar nerve damage. If the amount of in the hand warrants it there are many variations and combinations transplants which can be devised to improve function in these cases rationale and technique have been well covered in other works

BONES AND JOINTS

There are few secondary procedures of election on bones and jo offer much prospect of improvement in function beyond those of to correct bony alignment or joint fusion in an optimum position

Correction of Mal-union —Where extensive bone damage has oc soft tissue injury many fingers will have been amputated prima preserved will have had bony alignment corrected at that stage proportion however may still be seen later with lateral angulation deformity or overriding of bone fragments (Fig. 163) These defor usually associated with varying degrees of joint stiffness and a de usually to be made as to whether the finger should be amputated whole, or whether an attempt should be made to correct the def osteotomy and fixation in an improved position The indication for is more common in severe injuries with damage to more than one fing a finger though stiff at one or more of its joints may remain of great hand as a whole. Open osteotomies of this type often with re irregular or overlapping portions of bone can be followed by intern with small metacarpal plates and screws or simply by plaster retent period of several weeks

Correction of Joint Deformity —Of more common concern is which has stiffened in an unsuitable position either because of intra injury or because of prolonged fixation Whilst certain of these de can be corrected by slow traction, often combined with capsulotom the intermediate phase of treatment we are concerned here rather w fixed and intractable deformities requiring later secondary correction



Fig. 163

An unreduced fracture dislocation at the proximal interphalangeal joint treated by joint excision and wire fixation in a partly flexed position. In a simple finger injury this might be an indication for amputation, but when other fingers are also injured, as here, retention of such a finger becomes all important.

Fig. 164

Method of arthrodesis of a terminal interphalangeal joint

A, Mallet-finger deformity resulting from injury to the extensor expansion followed by sepsis and loss of tendon substance.

B, Radiographs following excision of joint surfaces and transfixion by Kirschner wire.

C, D End result with terminal joint fused in slight flexion.

We have not been impressed by arthroplasty of interphalangeal joints. The degree of active joint range and stability following these procedures is rarely sufficient to warrant them Stability is better gained by fusion of the affected joint in a position of partial flexion. Excision of the joint surfaces followed by transfixation with Kirschner wires and plaster in the appropriate position is the simplest method of arthrodesis (Fig. 164) Sometimes internal fixation with metal plates may be used in the case of the proximal interphalangeal joint (Fig. 165) On the other hand mobility is all important in the metacarpo-phalangeal joints and open arthroplasty may occasionally be of use for a fixed hyperextended joint which does not respond to capsulotomy and slow traction



Fig. 165
Arthrodesis of a proximal interphalangeal joint with internal plate fixation

Restoration of Bone Loss.—Occasionally in severe injuries where the retention and restoration of every potentially useful hand remnant is of first importance, bone grafts may be necessary to maintain finger length and to promote union and stability The indication is more frequent in war time and concerns chiefly the maintenance of metacarpal length in through-and through wounds where these bones are shattered Bone grafts to provide metacarpal length and stability in these cases are usually only a part of an extensive reconstructive programme involving also the replacement of soft tissue and tendons (Fig. 131)

In single finger injuries the scope of secondary operations on bones and joints is very limited and often it will be best to amputate the finger in the interests of the hand as a whole. Where a number of fingers is involved and preservation of every functioning unit is important, they may be of great value in stabilising bones and joints in the most useful position

CHAPTER XIV

UNSATISFACTORY AMPUTATION STUMPS AND ELECTIVE RE-AMPUTATIONS

WE have so far tried to avoid making any separate issue of finger amputations We have seen how any traumatic amputation can be considered in principle as an open wound and indications for amputation have been discussed with the particular injuries where they commonly present In secondary management, however it is convenient to discuss separately certain problems and decisions of elective amputation or re-amputation

Various symptoms may render the existing condition of an amputation



Fig 166

The unhealed discharging amputation stump—an old and oft repeated story

A, Neglected minor finger-tip amputation—with bone exposure and sepsis.

B, Persistent discharging wound three months later It was a further four months before healing was achieved after removal of sequestra, scar excision, and flap replacement.

stump unsatisfactory to its bearer He may present for advice or for treatment with one or more of the following complaints (1) It remains unhealed (2) it is painful or tender to touch, (3) it is embarrassing to the use of the hand, (4) it is unsightly

The Unhealed Amputation Stump—There are two clinical variants of this condition

A DISCHARGING SINUS most commonly results from the sequence of events which follows failure of primary closure over the bone end (Fig 166) Exposure of bone or cartilage results, and sepsis follows if it has not already been one of the precipitating factors Sequestration may take several months depending upon the blood supply of the part and the degree of sepsis. A sinus proves trying and annoying to the patient who seeks relief not so much on account

of pain but for the nuisance and tedium of discharge and dressings. The same sequence of events may follow the retention of foreign bodies or of free avascular pieces of bone resulting from a comminuted fracture, or from the careless splintering of bone with bone forceps The nut-cracker effect of these forceps may even involve longitudinal splits into neighbouring joints.

Where sepsis persists and sequestration is incomplete, secondary interference should be withheld Surgery should be confined to the removal of separated bone fragments after which spontaneous healing will occur If it does not, *there is strong reason to doubt completion of the sequestration process.*

Persistent Ulceration of the Stump—Any scar adherent to bone is prone to petty injury and ulceration The longer a stump remains unhealed the less the likelihood that it will ever heal spontaneously Here the best treatment is either to shorten the stump or to replace the unstable and adherent area with a skin and fat pad from another region This decision depends on the relative disadvantage to the hand as a whole of any further shortening of the stump to provide local soft tissue cover In general if the thumb or the index finger is involved or multiple amputations exist, repulping of a finger tip or recovering a stump by well-chosen flaps is preferable to proximal re amputation Re amputation is best applied to single amputation stumps of the middle, ring or little fingers, except where special circumstances indicate otherwise.

Painful Amputation Stump—Few amputation stumps which heal primarily and which are adequately covered by soft tissue become painful Failure to provide a healthy mobile soft tissue cover is the usual basis of pain Recent literature gives much emphasis to major neurological procedures for painful stumps We are frequently dumbfounded by cases which have undergone multiple operations on the nervous system where adherent scarring and the physical imperfection of the amputation stump itself have not even drawn comment It is our opinion that pain in amputation stumps is due to defects in healing or failure to provide adequate soft cover for nerves rather than to any condition of nerves themselves or their central connection We rarely see a genuinely painful stump which is well padded and devoid of scar adhesion to the surface. A terminal neuroma may or may not be associated with pain It is never the sole cause. The correct treatment is to excise the scar shorten the digital nerves if necessary and prevent recurrence of the chain of events by proper soft tissue cover

There are causes of painful amputation stumps of fingers other than that of adherent scar with nerve involvement These include —

1 Retention of Nail bed Remnants which may continue to grow Where nail remnants persist, they are soon manifested by a tender point which ultimately becomes a tender mass (Figs 167 and 168) The treatment is to resect all remnants of the nail bed The short anatomical distance between the distal interphalangeal joint and the nail bed must be remembered

2. Inclusion Dermoids in finger amputations occasionally cause symptoms very similar to those of nail bed remnants.

3 RETAINED FOREIGN BODIES such as glass metal and lead pencil tips may cause similar painful lumps.

4 AMPUTATIONS THROUGH JOINTS with cartilage under a terminal scar



FIG. 167

A tender mass, diagnosed as a neuroma, excised from finger amputation stump It was an area of reaction about proliferating nail bed remnants.

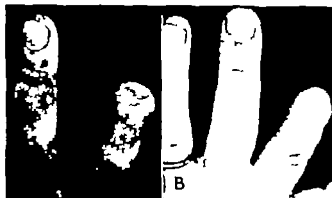


FIG. 168

Painful stumps

A, Remnants of nail bed may grow deformed rudiments of nail uncomfortable and sensitive to repeated petty trauma.

B, Symptoms relieved and appearance improved by removal of nail-bed remnant and trimming of the stump

Amputation Stumps which Interfere with Hand Function —Apart from pain and tenderness which might render any amputation stump an embarrassment to use of the hand a stump may get in the way or be a nuisance for various reasons.

1 It may be too short to be of use (Fig. 169) This usually applies in the case of an index finger which is shortened beyond the point to which the thumb

can oppose, in which case most people develop opposition between the thumb and the middle finger This leaves the index stump to stick out where it is a

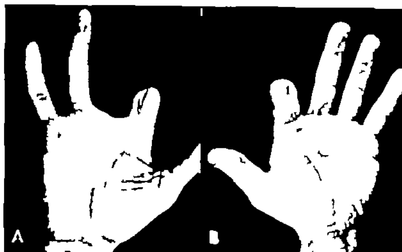


FIG 169

All considerations of amputation must be relative

A, It would be wrong to shorten this index stump in the absence of its neighbouring finger

B, The same stump in an otherwise normal hand might well be more nuisance than worth.

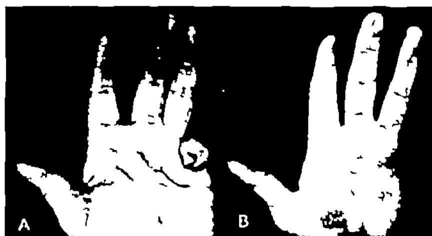


FIG. 170

A useless stump

Short stumps of the index and little fingers are frequently more nuisance than value.

A, Flexed and rigid little finger stump—a source of constant nuisance.

B, After amputation through the metacarpal.

nuisance and exposed to minor injury Short little finger stumps are also a frequent cause of embarrassment (Fig. 170) They take no part in the use of the hand as a whole and they too are subject to injury in their exposed position

2. It may be too long if stiff in a straight position This especially applies to the index and middle fingers if the tips cannot be opposed to the thumb

On the other hand, a stiff finger may be a very useful entity if shortened and in a conveniently flexed posture

3 A finger may be over flexed or over angulated by joint fixation or scars which cannot be eradicated These again have more nuisance value than worth,





FIG 171

Camouflage of unsightly finger stumps

The cosmetic value of well-made artificial fingers in selected cases is undoubted.

especially if the nail becomes the point of opposition or if a rotated stump interferes with movement of neighbouring fingers.

4 Anæsthetic stumps are frequently a nuisance. Their management must be guided by the likelihood of re-innervation and the possibilities of nerve restoration.

5 Metacarpal stumps may be too bulky This is frequently noted where there are remnants of thumb and fourth or fifth fingers with amputation of the

index and middle fingers through the metacarpo-phalangeal joints Better function often results from reduction of the bulk of the palm to increase the cleft between the thumb and remaining fingers.

Unsightly Stumps —Cosmetic objection to various finger amputations has been over-emphasised in the elaboration of so-called " sites of election " These cannot always be reduced to rules They must be based on individual considerations and values.

It is agreed however that certain finger amputations for certain people in certain occupations or of certain social status do have an unnecessary unsightly presentation Amputation of the index and little fingers through the metacarpo-phalangeal joints leaves knobs which are relatively unsightly The appearance can be improved to the satisfaction of some patients by a proximal amputation through the metacarpals of these fingers

Possibilities of prosthetic appliances on amputation stumps have some place in relation to certain work or conditions. Modern camouflage prostheses of this type have their application, especially for little and ring finger stumps in women (Fig. 171)

SITES OF ELECTION

Many rules have been laid down concerning sites of election for finger amputation We prefer to treat each case *individually with the following* principles in mind —

1 Conservation of length is paramount in the case of the thumb



FIG 172

A useful stump

This especially applies to the middle and ring fingers.

A, Shows the value of a short ring finger stump in maintaining the spread of the hand and preventing adduction deformity of neighbouring fingers.

B, Shows the disadvantage and deformity caused by more proximal amputations.

2 Amputation stumps of the index and little fingers which do not include a mobile proximal interphalangeal joint are generally redundant and of more nuisance than worth

3 *On the other hand* remnants of the middle and ring fingers are of great value in stabilising the posture of the index and little fingers and maintaining the integrity of the transverse arch. Embarrassing adduction deformities develop when these fingers are amputated through the metacarpo-phalangeal joints (Fig. 172)

4 The integrity of the metacarpal heads and transverse metacarpal ligament is important in the use of the palm during manual grip These structures should not be lightly interfered with in a manual worker

Technique of Elective Amputations

Finger amputation stumps are best covered by the more bulky flaps which can be obtained from the volar aspect than by dorsal flaps (Fig. 173) Dorsal scars which are off the point of opposition or grip are preferable to terminal and volar scars. Suturing of flaps should include the accurate apposition of



Fig. 173

Use of volar flaps

A, Recent amputation of finger tips trimmed and closed by volar flaps, at the time of removal of stitches.

B, The final appearance. Scars are well free of apposition and contact areas.

both skin and subcutaneous tissues so that there is always a soft tissue plane between skin and bone Sufficient sutures must be used to ensure that there is no pouting of fatty tissue Flaps must not be taut, and to ensure sufficient length of flap it is good practice to hold a finger flexed while a dorsal flap is cut and extended when a volar flap is cut. Some shortening of the bone end is preferable to tension suturing of flaps Tendons should not be sutured across the ends of finger stumps for this limits movement

Digital nerve trunks should be shortened to ensure that their ends are buried in fat and clear of the suture line. Ligation injection and crushing of cut nerve ends serve no good purpose and should be condemned

Amputations through the distal phalanx raise the problem of retained remnants of nail bed. To ensure complete excision of the nail bed it is necessary

to remove the dorsal periosteum as far proximally as the extensor tendon insertion and around the sides of the phalanx to include its most lateral limits.

If for any particular reason amputation through a joint is decided upon the articular cartilage is removed and the bulk of the condyle reduced When amputation through a joint is specifically designed however to avoid bone sepsis it would be wrong to trim the bone end in this way

Complications of elective finger amputation are distressing and commonplace In most cases they can be related to defects of technique or the relegation of this operation to the inferior facilities and organisation which so often exist in so called " minor surgery "

CHAPTER XV

RECONSTRUCTIVE PROCEDURES FOR MUTILATING *INJURIES*

IN the management of the more destructive hand injuries mere restoration of residual parts to normal is sometimes insufficient. Good healing and function of the remnant do not always represent the optimum result (Fig. 174) Due consideration must be given to the possibility of substitution for parts which are lost The greater the damage, the stronger is the indication

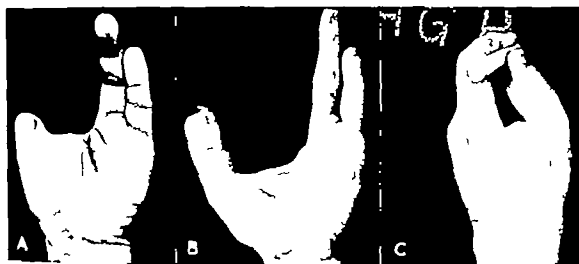


Fig 174

Reconstruction of lost digits

A, Healed hand remnant with short thumb stump and scar limitation of extension in ring finger
B, C, Show the value of lengthening the thumb stump together with scar excision and a whole skin graft about the base of the ring finger

for operations which might well be considered uneconomic for less damaged hands (Fig. 175)

Many time-consuming operations were performed for severely mutilated hands resulting from the past war Many of these operations are now only of technical interest and are not often used Some, after fair trial are now accepted procedures to be known and considered by all concerned with hand injury and repair The procedures of most value concern the restoration of the pinch function. Normally this function requires an intact thumb For its restoration to a mutilated hand three requirements must be satisfied (1) The thenar muscles must be present and active in a functioning state of integrity attachment and innervation (2) there must be an adequate length of thumb (3) there must be an adequate length of finger or fingers to which the residual

thumb length can be apposed in the movements of opposition and flexion. Hands may be left without pinch function by defects in one or more of these



FIG 175
Indications for reconstructive operations are relative to the severity of injury

three factors In such hands pinch function can often be restored by one of the following means —

1 Reconstruction of apposition digits
2. Pollicisation of another digit.
3 Deepening interdigital clefts.
4 Prosthesis.

RECONSTRUCTION OF APPOSITION DIGITS

If the thenar muscles are present and have some function an existing stump can be lengthened or a whole thumb reconstructed It is also practicable to make a rigid digit against which a normal thumb can be opposed Moreover where all fingers are missing both elements can be reconstructed In each of these procedures which answer different indications pinch function is restored in some effective measure (Fig. 176)

In an earlier report of our own experience [1] of these methods easy pitfalls are indicated and the precautions necessary to forestall them are set out below in a description of the basic procedure Experience since that time has not changed our views If the results of plastic surgery are erratic or equivocal it is uneconomic For this reason the shortest means of obtaining an end result, if associated with a high risk factor is not always the best procedure for general application Though an apposition digit can be made in less stages, we consider a four stage operation the most satisfactory means to this end

Stage 1 Raising a Tube Pedicle—*A standard tube pedicle is made in a* convenient position on the abdomen or in the acromio-pectoral region with due regard for hair disposition Each site has advantages for individual cases.

Rank B K & Wakefield, A R. (1945). Reconstruction of opposition digits for mutilated hands. *Aust N Z J Surg* 17 172.

The skin circumference of the tube corresponds exactly to that of the stump As future circulatory insufficiency arises rather from too much than too little

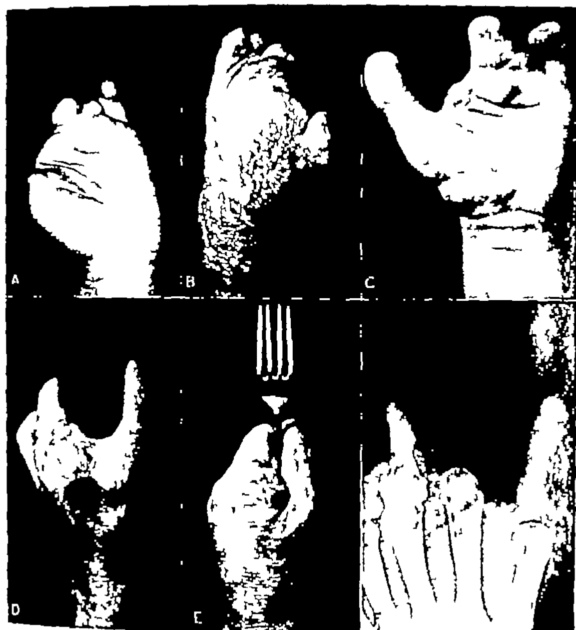


FIG 176

Reconstruction of apposition digits

A, B, Healed hand remnant four months after injury in a circular saw accident.

C, D E, Show the condition one year after reconstruction of apposition digits by extensions from a remnant of the proximal phalanx of thumb and from the head of the middle finger metacarpal. The useful range of movement is demonstrated.

F Radiograph taken five months after the bone grafting operation—shows the bone graft *in situ* and united.

fat in the pedicle, and as a bone graft has later to be accommodated in its core at a stage when trauma to fat is undesirable, the pedicle should be made lax by appropriate fat reduction at its initial construction

Stage 2 Attachment of Pedicle to Hand —The appropriate end of the tube pedicle is detached from the abdomen or chest A ring suture line of the pedicle around the stump is undesirable. The largest possible surface contact between the free end of the pedicle and the recipient area ensures a good attachment (Fig. 177)

The tubing of a flap and its attachment to the stump at a single stage is not advised The junction of two recent suture lines in two planes at a vulnerable

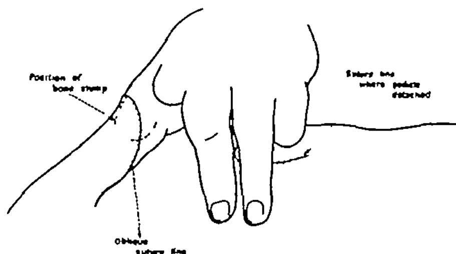


FIG. 177

Method of attaching pedicle to thumb stump

An oblique suture line is important

(Reproduced by permission from A [illegible] and N Z Journal of Surgery Vol XVII [illegible] page [illegible]—Rank and Wakefield)

site is always prone to minor breakdown Tubing at a preliminary stage precludes this risk

Stage 3 Detachment of Pedicle from Abdomen —The pedicle is severed from the abdomen to leave the length required on the hand for the apposition digit.

Some fat is removed from the free end to allow of its accurate closure without tension after it has been trimmed to avoid a chaff sack appearance This blind end of graft tissue has a low grade vitality

The terminal suture line unites slowly so that sutures must not be removed early Any failure of first intention healing means long weeks of secondary healing sometimes requiring secondary excision and resuture.

This stage although it involves the simplest operation is often the most difficult

Stage 4 The Bone Graft —*The longitudinal suture line of the pedicle* is reopened about half to one inch short of the distal end and extending on to the normal tissues of the hand if necessary The bone stump is trimmed and its medulla is gouged out

Cancellous bone *from the iliac crest is used One end is fashioned* as a peg to be dowelled into the stump of metacarpal or phalanx the other end is rounded (Fig 178)

The graft is arranged in the core of the pedicle and pegged into the open bone stump with as little disturbance as possible. Supplementary free fragments of bone can be used about the proximal end of the graft A few buried catgut sutures unite the fascial and fat layers over the graft and the skin is sutured with silk The digit is splinted in correct position by a complete plaster which is left undisturbed for about a month *Immobilisation and protection of the graft junction are* continued until clinical union is sound (Fig. 179)



Fig 178

The cancellous bone graft

Radiograph showing how the graft is shaped and pegged into a stump of phalanx or metacarpal

During after-care due precautions must be taken in regard to the anæsthetic area—a local, well fitting glove is worn appropriately thick in cold weather These precautions are required throughout the period of sensory return *i e*, for about twelve months

In the reconstruction of paired apposition digits the same pedicle is used for both digits It must be proportionately longer, and one extra operation stage is required for the programme (Figs 180 and 181) The stages of this procedure are (1) Raising a long abdominal tube pedicle (2) attachment of one end of the pedicle to the thumb or finger base, (3) attachment of the other end of the pedicle to finger or thumb base to make a soft tissue U loop (4) division

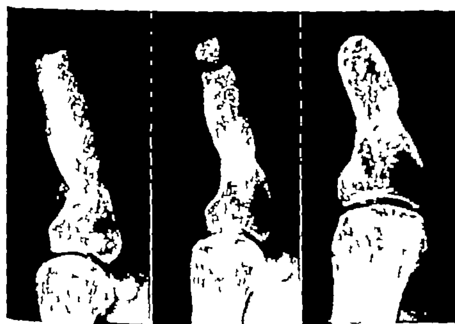


Fig. 179

Changes in a cancellous bone graft with time and function

Serial X-rays taken over a period of two years following digital extension by tube pedicle and cancellous bone graft The aseptic necrosis of the tip of the graft concomitant with progressive union at its proximal end is significant of varied blood supply The ultimate union, shape adaptation, and the compact surface change in the graft are typical of adaptive behaviour of cancellous bone



FIG. 180

Stages in paired digital reconstruction



Fig 181

Stages in paired digital reconstruction

Figs. 180 and 181

A, Hand remnant after a hand grenade injury
B Stage 1 An abdominal tube pedicle.
C, Stage 2 Attachment of the pedicle to the thumb remnant.
D Stage 3 Detachment of pedicle from abdomen and attachment to the ulnar region of the hand.
E, Stage 4 Division of the pedicle loop
F G Stage 5 After bone graft extension of a mobile thumb remnant and the immobile ring finger metacarpal Other metacarpals have been reduced. H, I, J K, L, Radiographic story

(Medical War History.)

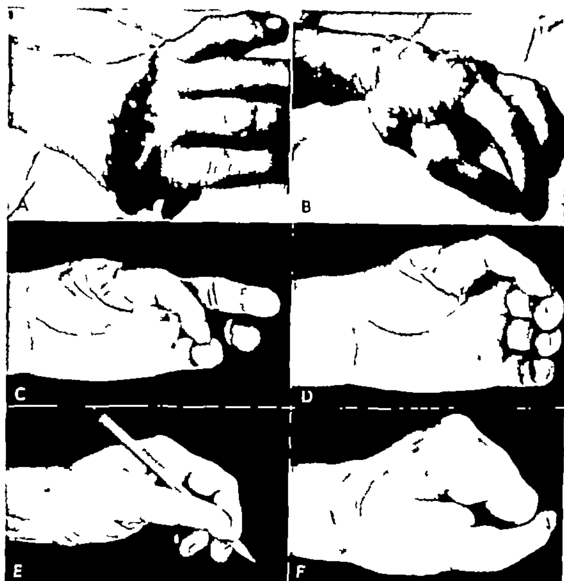


FIG. 182

Pollicisation of an index finger

A Recent hand injury with amputation of the thumb through its metacarpal. Open fracture of index and middle finger metacarpals and severed extensor tendons. Pollicisation of the partly amputated index finger was commenced at primary operation when the extensor tendons to neighbouring fingers were also repaired. B, The state achieved at the primary operation.

C D E, F Illustrate the ultimate result after secondary operations for further widening of the interdigital cleft by flap rearrangement and free graft, splitting the common volar digital nerve plate fixation of the transferred digit to thumb metacarpal and transfer of the long flexor of the transferred index finger to the flexor pollicis longus motor



FIG 183

Pollicisation of an index finger

G H I, Radiographs are self-explanatory and correspond to stages B, C, etc.

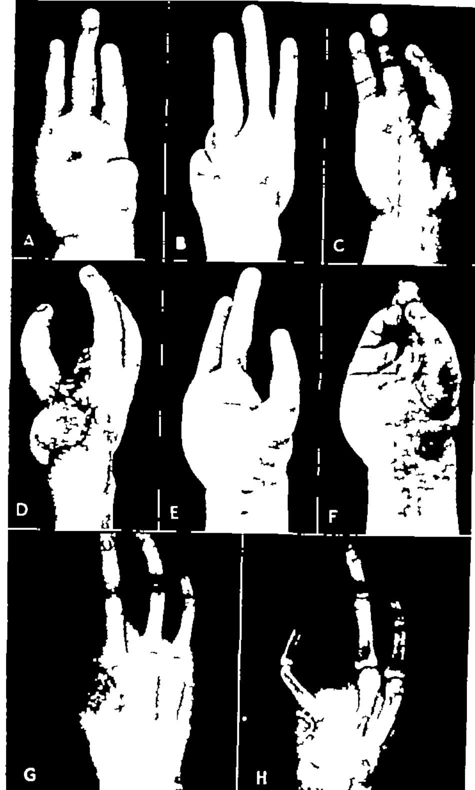


FIG. 184

Pollicisation of the middle finger

A, B, *Hand remnant after circular saw accident. Thumb and index fingers* missing, also most of the middle finger metacarpal.

C D After first stage of transfer of middle finger stump. An angled plate was used to fit the proximal phalanx to the carpus at this stage. Apposition was still imperfect, so rotation osteotomy of the ring and little fingers was carried out. E F Final result. G H Radiographs before and after transfer of the digit.

of the U-loop to make separate and appropriate lengths of soft tissue extension on the thumb and finger base (5) bone grafts to both digits

Stage 5 Restoration of Sensory Function—Though this method of reconstructing a thumb was commonly applied to war time injuries the development of other procedures, especially pollicisation of a finger has reduced the frequency with which it is used The chief disadvantage has been that of sensory deficiency The development of the island flap transfer however (p 208) brings new possibilities to this method, and it can well be added as a fifth stage of this programme in the case of a thumb extension [1] An area of innervated skin from the pulp of another finger is transferred to the essential sensory region of the reconstructed thumb on a neurovascular pedicle. This may well restore the method to a position of favour

POLLICISATION OF A FINGER

Where the thumb is missing, the advantage to the individual of transferring the index finger to the site of the thumb should be considered This is now a well-tried operation Though various methods of achieving this end have been described, they generally involve at least two stages Each procedure however is largely a matter of surgical opportunism

Some degree of movement can be retained in a transferred finger and what is more important, the index finger can be transferred with its sensory innervation intact. This is possible because the common volar digital nerve can be separated into its digital components well proximal to its bifurcation

The results of this operation for well selected cases have proved most satisfactory At one time we were disinclined to interfere with a normal index finger and only considered pollicisation when the index finger itself had been damaged (Figs 182 and 183) However the method has proved so effective and safe that it is now done if the indications exist even if this means moving a normal finger

Pollicisation of a toe is an interesting suggestion and an ingenious feat of endurance for surgeon and patient It cannot be seriously regarded as a practical contribution in the face of the alternatives which exist

DEEPENING INTERDIGITAL CLEFTS

Any approach to this type of surgery with fixed ideas can easily lead the surgeon into long and difficult procedures when a simple and effective one-stage operation is staring him in the face. Pinch function is often well restored to the palmar region by fashioning clefts between individual metacarpals. This is generally applied to increase the freedom and usefulness of the mobile first metacarpal (Fig. 185) Even where there are no digital remnants this type of operation is often most effective, giving some value to an otherwise useless flipper (Fig. 186) The methods of achieving this end are protean, and in some cases it is well combined with extension or reconstruction of opposition elements (Fig. 187)

[1] Littler W Personal communication.



Fig 185

Making an interdigital cleft

A, Hand remnant with no value after machine accident.

B C, After establishing a cleft between the thumb remnant and the third metacarpal—one operation The second metacarpal was removed with its attached interosseous muscles. The adductor pollicis was split through most of its depth, a dorsal flap brought through the cleft and the remaining areas covered by local flaps and free grafts.

PROSTHESIS

Where the thumb only is present and other fingers are missing, a mechanical prosthesis is of more value than surgically reconstructed digits in certain individuals and occupations (Figs 188 and 189)



FIG 186

Hand cleavage

A, D Remnant of carpus and metacarpus without mobility—result of gelignite explosion.

B C, E, Show the result after removal of the central bone column, and the fashioning of a cleft between the two lateral elements. Adduction movement was obtained by crossing and elongating the flexor carpi radialis and flexor carpi ulnaris by free tendon grafts inserted to the lateral bony columns There was independent abduction of the radial element by the abductor pollicis longus. The patient can now usefully manipulate and grasp small objects.



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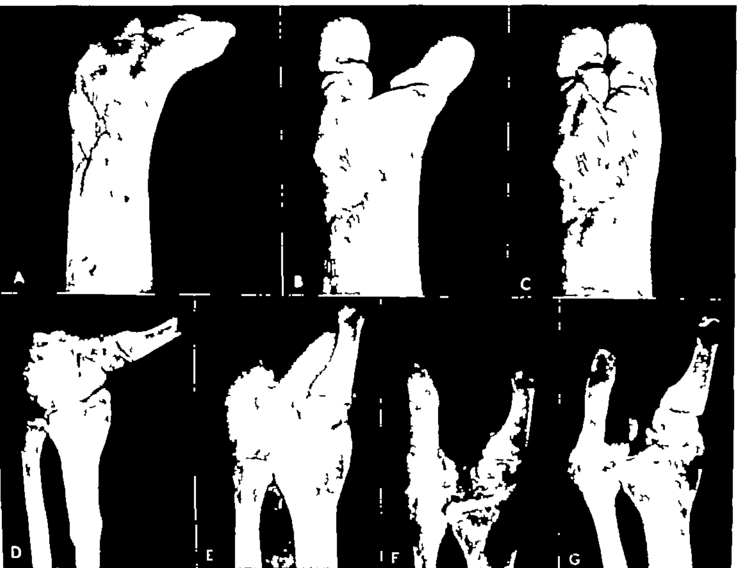


FIG 187

Hand cleavage and extension of digits

From the hand remnant shown in A, the result indicated in B and C was obtained by a combination of procedures, including selective removal of carpal bones, soft tissue and bone graft extensions of the thumb metacarpal and from the ulna—positioned

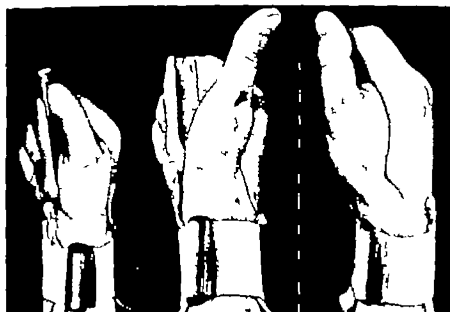


FIG 188

Opposition prosthesis

A lone thumb remnant can be rendered more effective by a fitted prosthesis against which it can oppose The prosthesis illustrated is made in acrylic.

FIG 189

Prosthesis for special purpose

This lad, a butcher boy required some means for grasping his knife. The acrylic prosthesis in B, though very effective, proved too fragile He had a replica cast in metal, C and D

PART FIVE—Chapters XVI to XVIII

SPECIAL ASPECTS OF HAND INJURY

CHAPTER XVI

THE BURNT HAND

THIS is no place for discussion of the many general principles and probl concerning burns and their management. It is our purpose to cons the particular application of these matters to burns in a specific regic the hand

A wide divergence of opinion concerning the optimum local treatment a burn is frequently noted in medical literature and at surgical discussi This is explained more often than not by the fact that the surgeons concei have had special experience with a particular type of burn under set condit or at a certain phase in its clinical history Some have had access to sp organisation and facilities some have not some have been concerned n with children some with adults some work in modern cities, some an country outposts some treat civilian victims of industrial accidents, some service casualties of war-time actions which again vary among soldiers, sa and airmen Such diverse factors accentuate particular aspects of the ger burn problem which embraces no end of conditions and arrangements.

It is therefore a principle in itself that methods used in the manageme burns must be variable and adaptable Realisation of this would solve n arguments or render them futile.

Despite our present concern with burns in a special area we must cl recognise the fact that no part is greater than the whole. Whenever the any question of threat to life, burns in a particular region even of the h or eyes, become only secondary to the proper general management of the b patient With this proviso burns of the hand do warrant separate considera first on account of the overwhelming frequency of exposure of hand burns, and secondly on account of the havoc to function and livelihood w may follow

TWO MAIN TYPES OF BURNT HAND

Exposure Burns—Along with the face, the hand is the most frequ severely damaged region in exposure to flame or intense heat. Ce tures have a bearing on the nature and management of exp hands are generally affected for the same reason—lac acks of the hands and fingers suffer most damage bec hed and held to the face and because the skin is so are often only part of a more general burn w the body surface, depending on the intensity o t of clothing or other protective agents wo tions of burn shock may ensue. Modern l in many works. The wide variation n ck among burns of equivalent areas t

that this problem concerns far more than mere area of involvement Depth of burn is no small contributing factor and perhaps it is for this reason that badly burnt hands contribute more to shock than their mere 4 per cent. of body surface area might suggest Furthermore, the loose areolar attachment of skin to under-structures on the back of the hands permits of more than ordinary accumulation of fluid loss in this region

Exposure burns of the hand are seen among victims of "bushfires," burning buildings, explosions of petrol and other inflammable agents. The *airman's burn is a classical and frequently severe example of this type.*

Contact Burns —For obvious reasons the hand far more than any body



Fig 190

A friction burn—in this case from contact with the side of a rapidly revolving saw plate (*inset*).

region is exposed to injury by contact with hot objects or burn-producing agents Burns so caused range in severity from common household accidents with spilt tea, boiling fat or matchbox explosion to the childhood catastrophe of grasping an electric radiator element Such burns are common too in industry About 8 per cent of reported industrial accidents are burns. Heated metal, splashed molten metal or explosives are day by-day causes of burnt hands. Acid or other chemical burns, friction or brush burns (Fig. 190) and electric contact burns produce *similar le* *Local hand burn* be further complicated by mechanical t same injury moulding presses or laundry of the and crippling hand injuries that are een

The features of contact burns which contrast with exposure burns and which have a strong bearing on their management are as follows —

1 They generally involve only one hand
2 They frequently concern the palmar aspect of the hand
3 They are often discrete areas of deep burn
4 They are usually an isolated injury and rarely part of a more extensive burn.

There is rarely any threat to life from shock so that local treatment can be conducted on more specific and radical lines to suit the nature of such burns

PROGNOSIS OF A BURNT HAND

As with any soft tissue injury the degree to which full recovery of function can be expected is conditioned by the extent of anatomical damage and the effects, direct or indirect of secondary intention healing Direct effects are due to the amount of fibrosis or scar tissue which is formed and to its secondary contraction Indirect effects concern the results of immobilisation swelling and œdema or disuse. Joint contractures and deformities muscle wasting and fibrosis are some of them.

If therefore, the optimum is to be expected from any burn of the hand it is essential that no further damage is inflicted and that the healing time is minimal. **The prognosis is directly related to the healing time** The shorter this is the less fibrosis and the less opportunity for adverse side effects of slow healing.

The main factor therefore, in the prognosis of a burn is the mechanism of its healing and the time which this takes This process occurs by one of two entirely different means, depending on whether or not the skin is entirely destroyed. Is the skin capable of spontaneous regeneration from the whole area or only from its margins ?

In view of the bearing this has on prognosis and on local treatment the diagnosis of the depth or degree of a burn if it can be made, has singular importance.

DIAGNOSIS OF THE DEGREE OF THE BURN

In extreme cases this is easy but in the borderline cases which are common it is extremely difficult and can rarely be made with certainty If the skin is charred dead white and avascular or mummified it has obviously suffered a full-thickness or third-degree burn while, if there is erythema or intracutaneous blebs it is obvious that circulation in the dermis is still active and that the burn, therefore, is not a full thickness burn These appearances may vary somewhat in the early hours following a burn especially where the skin is thick and where blistering is concerned.

Unfortunately many cases show borderline features. Moreover the common burn is rarely of a homogeneous nature It is an irregular mosaic

of mixed areas of second and third degree. Where the skin is thick, as on the palm of a hand, assessment of depth is always more difficult (Fig. 191) The thick horny skin of a manual worker makes this diagnosis impossible. Absence of pain sensitivity may be helpful in indicating complete skin destruction but it is better in most cases to give the benefit of doubt to a diagnosis of the lesser degree. Thus, management will follow one of two lines, viz. (1) That of second-degree burns including those of dubious nature in which there is possibility of spontaneous healing (2) that of third-degree burns with complete skin destruction incapable of spontaneous epithelialisation



FIG. 191

The difficulties of depth diagnosis

Diagnosis is always difficult in areas where the skin is thick In this case the two white areas would appear to be third degree burns. In fact they were both spontaneously healed within two weeks, *i.e.*, the whole skin depth was not destroyed.

TREATMENT OF A BURNT HAND

If the general arrangement under this heading reproduces that of the book as a whole it serves further to emphasise how the same generalities underlie the surgical management of all soft tissue injuries. The problems of local tissue damage, healing and repair vary but little with the agent or mechanism of destruction

The principle of **organisation** is reiterated so is that of **continuity in management** It is assumed that proper surgical conditions and ability are available.

FIRST AID AND CASUALTY TREATMENT

It is not good policy to teach that any burns of the hand are of minor nature In addition to the non specific indications for any burnt patient, first aid should be limited to the provision of a clean if not sterile cover with a minimum of local handling and interference until facilities for proper primary treatment are available There must be no time lost in making proper anti-shock measures available to any severely burned patient and this aspect must always take precedence over early local treatment.

PRIMARY TREATMENT

SECOND-DEGREE BURNS AND BURNS OF DUBIOUS DEPTH

Here the object of local treatment is to facilitate normal healing by preventing or reducing all known factors which can delay this and so make for abnormal healing.

The rate of normal spontaneous healing of a second-degree burn will depend on the depth of the burn because the amount of undestroyed epithelium from which regeneration must occur diminishes the deeper the burn extends through the dermal layers. Any agent or complication which adds further epithelial destruction must be avoided Sepsis is outstanding among such causes of delayed healing. Local primary treatment therefore, is best directed to the prevention and control of secondary infection of the burnt area.

A second-degree burn will do well under any clean method of treatment. **There is a vast difference in prognosis between a burn which is not secondarily infected and one which is** Sepsis may so add to epithelial destruction that a second-degree burn which was capable of spontaneous healing is converted to a third-degree burn, *i e*, an area of complete skin loss which can only heal from its margins The prevention of sepsis in burns and its important ramifications have been fully investigated and are discussed by Colebrook [1] We uphold his important teaching, and with minor variations practice the method of local treatment which he advocates

When and only when the patient s general condition is under control the local treatment of the burnt hand is conducted on the following principles —

CLEANSING —The part is washed over with 1 per cent solution of Cetavlon using gauze swabs Blisters may be opened with scissors and loose skin shreds removed This does not mean peeling off large areas of protective epithelium Dead skin is a nidus for infection, and the exudate of a burn is a good culture medium, whether contained within blebs or saturating a warm dressing.

DRESSING —The burnt areas are covered by a single layer of tulle gras. This is non-adherent and allows free escape of exudate to the outer absorbent dressing made up of many layers of flat cotton gauze The hand and fingers are then bandaged firmly but not tightly with sterile crepe bandages using small bandages around each separate finger Outside this, large masses of wool are arranged and further firm bandages applied Bandaging must be done with care and precision for though pressure is useful in controlling exudate and œdema its dangers must be properly realised to avoid circulatory embarrassment to peripheral areas With this in view it is best to incorporate the whole hand in a pressure dressing, no matter what area of it is burned

IMMOBILISATION —The hand is immobilised in the position of function **Early healing rather than early movement** should be the object of early treatment

If the wrist is uncontrolled a patient will generally hold the burnt hand with the wrist flexed This avoids activity of the dorsal tendons and relieves pain From this posture with dorsal skin on tension hyperextension of metacarpo-phalangeal joints can rapidly develop Hence the importance of maintaining wrist extension and metacarpo-phalangeal flexion from the very beginning of treatment

[1] Colebrook, L (1950) *A New Approach to the Treatment of Burns and Scalds* London Fine Technical Publications.

ELEVATION OF THE HAND (Fig. 192) aids the control of swelling and œdema during early days of treatment. Pain is eased in the elevated posture.

CHEMOTHERAPY.—Rather than the local use of antibiotics on burnt areas, we prefer to rely on parenteral administration of penicillin in all cases of severe



FIG. 192

Elevation and rest

Simple elevation of the hand by pillow arrangement is considered preferable to the common practice of suspending plasters which in itself may cause constriction and pressure effects.

burns for the first few days. The subsequent use of this or other antibiotics should under no circumstances become a ritual of ringing the changes every few days, but should be reserved for specific organisms and specific occasions such as the period immediately preceding or subsequent to grafting operations. In general appropriate dressing techniques, drainage and lavage will achieve more than antibiotics in the control of surface sepsis.

THIRD-DEGREE BURNS (COMPLETE SKIN DESTRUCTION)

Here it is obvious that the sooner the skin loss can be replaced the better will be the result. In some contact burns this can best be effected by primary excision of the burnt area and primary skin grafting of the defect. If this ideal of primary excision and grafting is to be practised the area should be clinically obvious as third-degree burn. Moreover it must be of such size, distribution, regularity and situation that it can be excised without further anatomical damage. The patient's general condition must not be jeopardised by the procedure, and the local facilities must be suitable for such an operation. These conditions are most commonly encountered in some of the more specific types of industrial burn of the hand. A general anæsthetic is necessary and the burns are excised to a healthy base. Determination of what constitutes a healthy base is the keystone and at the same time the difficulty of this method

Closure of the resulting surgical defect follows exactly the principles set out in Chapter VI. After proper hæmostasis the area is grafted usually with split skin. Exposed structures may indicate a skin and fat flap The indications of technique, design dressing and after-care pertinent to these procedures have all been considered

Surgical excision of some burns may imply local, or occasionally complete amputation of finger, fingers or even the hand (Fig. 193) The indications for local amputation and the time when this should be done vary considerably with the degree of destruction the exact region involved and the patient's general condition and morale

Wholesale application of the method of primary excision for all localised third-degree burns without respect of the conditions which have been indicated may lead a surgeon and his patient into an unhappy predicament There are



FIG. 193

Indications for amputation with local burns

As with any injury damage to essential structures of fingers beyond hope of repair indicates early amputation.

many areas on the hand where it is quite impossible to be sure whether excision has been wide of burnt tissue Decisions as to viability of tendons and bone in areas where they lie superficially are difficult A period of conservation will preclude such an impasse Whatever the value of primary excision of third-degree burns in other areas, we have had much cause to modify our views regarding its application to the hand In any case of doubtful extent we now prefer to adopt a policy of watchful expectancy until clean demarcation allows precise removal of what is dead and careful preservation of what is alive

If a conservative attitude is adopted the management of third-degree burns at this stage differs in no way from that already considered in relation to second-degree lesions.

ELECTRICAL BURNS

This subject warrants special discussion because most electrical burns involve the hand They generally have an unusual depth and severity relative to the surface area involved The term " necrosis " is perhaps more apt than

that of burn for these lesions The damage depends partly on the voltage, but the amperage, or amount of current is more important. Alternating current is more dangerous than direct current. Its duration and the position of contact points also affect the severity of the burn [1]

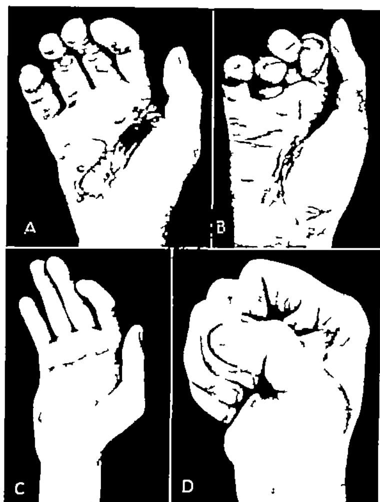


Fig 194

Electrical burns unsuited to primary excision

A, The indeterminate extent and involvement of vital structures generally render areas of electrical necrosis on the hand unsuited to primary excision. Early conservation is indicated, at least until the extent of necrosis is declared and separation commences.
B, The hand healed after separation of the slough and split-skin graft, with gross scar contracture, affecting tendons to index, and extreme local sensitivity from involvement of the digital nerves to thumb and index.
C, D The end result after scar excision and replacement by a flap of abdominal skin, removal of the flexor sublimus to index and tenolysis of the flexor profundus.

Two facts in the nature of electrical burns have some bearing on their behaviour and management (1) With the exception of bone, skin of all the tissues offers the greatest resistance to an electric current This is diminished

[1] Critchley MacDonald (1935) Injuries from electricity and lightning. *Brit med J* 2, 1 17

if the skin is wet. No matter, therefore, how small the contact point skin necrosis is pathognomonic of severe necrosis in underlying tissues (2) Blood, like cerebrospinal fluid has the lowest resistance of body tissues This accounts for the spread of damaging effect along blood vessels which may undergo a slow diffuse and spreading degeneration with secondary thrombotic changes With a severe necrosis there is always the risk of secondary hæmorrhage so that any amputation or vascular ligation should be well proximal to the lesions

It is not always easy to be sure of the limits of these lesions, and in many cases the anatomical structures involved in the hand are so important that sufficiently radical surgery to guarantee a complete excision of all damaged tissue is not always wise, *i e* the ideal is not always practicable The principle of primary excision therefore again must be tempered in its application to individual cases, especially where tendon, nerves and bone are likely to be damaged (Fig. 194) It is this difficulty of adequate excision which has often led to these burns being regarded as "spreading" (Fig. 195) If they are not excised, electrical burns are often slow to separate their slough, for infection is generally absent. Healing is slow and there is a large residue of fibrosis Nevertheless we feel that a delaying policy is generally the lesser of two evils, until such time as precise secondary débridement can be carried out



Fig 195

Apparent "spreading" in an electrical burn

Two weeks after an electrical burn of the hand. The damage includes complete necrosis of one finger The extent of damage to essential structures is still indeterminate. When first seen the ring finger appeared quite viable and the burn was not regarded as a severe injury

DELAYED TREATMENT OF BURNT AREAS

Early After-care —This depends on the severity of the burn whether or not infection ensues and whether or not the burn proves of second or third degree. Most exposure burns are mixed areas varying in their degree of depth destruction and distribution

Every dressing or exposure in the early stages increases the chances of secondary infection, cross-infection or reinfection Secondary dressings should only be done for a purpose Most primary dressings are undisturbed for a period of ten to fourteen days, except to be reinforced or occasionally changed when seepage of exudate occurs. By this time the nature of the burnt area should be clearly apparent and subsequent treatment depends on the findings.

(1) Clean and superficial second-degree burns or burns which have already been primarily excised and grafted will be healed All recently healed areas should be kept covered and protected until stability is ensured

(2) Deeper second-degree burns will not at this stage be healed but

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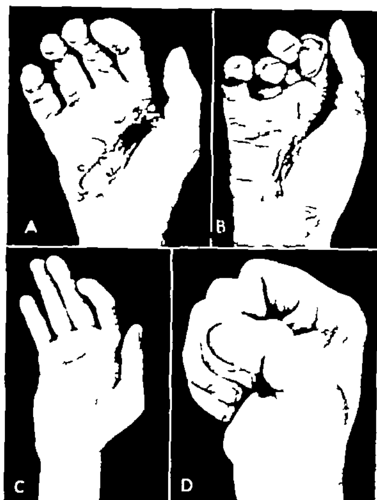


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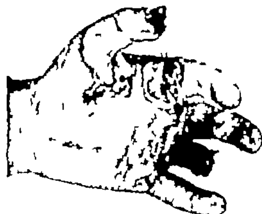


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(2) Deeper second-degree burns will not at this stage be healed, but

epithelialisation is seen from the many remaining islets of epithelium in the dermis. In some cases a layer of dermal tissue and adherent fibrinous exudate persists on a deep second-degree burn without apparent change for weeks. It is of advantage to remove this during the third week when a cleavage plane can be found which leaves a base suitable for immediate grafting. This has the advantage of preventing the gross hypertrophic scars which generally result from deep second-degree burns of this otherwise slow healing type.

(3) Areas of still deeper burn (third degree) will be manifest by obvious slough formation in which case the object of future management is to make good the skin loss as soon as possible It would seem that the period necessary for the separation of slough is longer in the absence of sepsis It is to the patient s advantage therefore to use any appropriate opportunity to hasten slough separation There is no sure means of cutting short this period except by excision or dissection of slough Pyruvic acid has been tried for this purpose, but we prefer surgical removal

Aware of the secondary procedures ultimately necessary for dorsal burns in groups (2) and (3) surgeons who are experienced in observation of these injuries and practised in skin grafting techniques may take a more active line of treatment with much advantage As soon as the extent of the burn becomes obviously one of deep second (or third) degree whether or not there may be a few dubious or viable areas, a formal excision down to the areolar plane which overlies the tendon system is carried out and a well-cut thick split skin graft is applied Thus an excellent finite result is achieved in a minimum of time uncompromised by any scar of spontaneous healing or the need for intermediary stages of palliative grafting

In some areas a frank secondary excision of the area now obviously manifest as a third-degree burn may be practised This, however must be applied with caution where deep structures are likely to be exposed without cover by soft tissue or granulation For most cases a regime of baths and wet dressings during the later period of slough separation facilitates the process, and it is well suited to early conditioning of the granuloma for a skin graft Alternating days of hypertonic saline and eusol packs beneath pressure bandages make a good routine after a daily hand bath of hypertonic saline Third-degree burns are usually ready for skin grafting during the fourth week after injury There are two areas of the hand where this period of slough separation is longer if delayed débridement or dissection is not practised These are (1) Deep burns on the palm of the hand where tissue is destroyed down to the level of the palmar aponeurosis from which dead areas are slow to demarcate (2) deep burns on the dorsum which involve the extensor tendons, bone or joints Not only is it difficult to determine the depth and extent of these burns but the lines of demarcation develop slowly The rate of separation varies in different tissues and regions depending on the blood supply

Though secondary débridement and slough excision have a rightful place in the early secondary treatment of deeper burns on the hands they must be used with caution and respect They must do no more than assist the selectivity of natural processes in dividing live from dead This especially applies where

exposed tendons are concerned. The ultimate results from the more conservative management of such cases, especially in children give frequent cause for surprise The ideal of any secondary surgical débridement of a burnt hand should be removal of all dead tissues without making the base bleed More than a little bleeding indicates unnecessary damage to viable areas. For example, the exposed surface of a tendon may appear dead, as it probably is, but its deep surface with vincula or other synovial relations intact may be very much alive and potentially a functioning unit. This has been noted time and again in the deep destructive radiator contact burns seen in children

Infected Burns—For burns which are first seen when heavily infected more frequent secondary dressings and more persistent or specific use of antiseptics or antibiotics are indicated. Free use is made of baths for mechanical cleaning of the purulent areas preparatory to the local use of penicillin or other antibiotic agents appropriate to the type of infection Persistent infection with Gram negative organisms including pyocyaneus infection is one of the main problems of the antibiotic era for which to date we have had no satisfactory remedy other than repeated physical cleansing of the wound surface.

Preparation for Grafting—As soon as the slough is separated a few days continued preparation with hypertonic saline baths and pressure dressings conditions a granuloma for grafting. Granulation should be firm, flat bright pink and without profuse discharge The absence of pain is a valuable guide to the control of infection Split skin grafts are generally used to achieve skin cover though if the discharge has been profuse, fragmented grafts either as patches of split skin or as pinch grafts are a good palliative to effect early healing. Subsequent replacement by thicker or more uniform grafts may be necessary at a later date.

If for any reason, wounds have been granulating for long periods, a better base for grafting is provided with less ultimate fibrosis if the granuloma is lightly curetted off Hæmostasis is obtained by hot packs, local pressure and lapse of time before applying the grafts

For still older granulating areas in long standing burns which have failed to heal in their entirety it may be better to carry out a formal excision of the area and to graft the surgical wound which is created

With deep burns of the fingers at this stage exposure of important structures open joints or massive areas of necrosis may necessitate amputation This is best done through joint regions because bone sepsis is almost certain if bone is sectioned

After-care of Recently Healed Burns—All recently healed areas should be protected by dressings for a period depending on their position the subject and his activities. Light application of lanoline prevents drying and cracking. Purposeful exposure to sun should be avoided Active exercises should be practised to the limits of function without straining and stretching, realising that scar resolution is essentially a feature of time and not of the vigour of subjective or objective over activity

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The interplay of factors which produce hand disabilities after burns are represented schematically in Fig. 196 Some of these are reversible processes, some are not It will be deduced that the ultimate result is largely determined by whether or not postural deformities of joints and fixations of the intricate locomotor complex of the hand are retrievable. If joints are not deformed and if movements are not seriously limited, there is every advantage in delaying secondary surgery until scars have reached a stage of maturity and softness. This is often impossible because function of the many small joints is so handicapped by scar that corrective operations have to be done earlier than in other parts of the body where bigger joints are concerned

THE COMMON BURN SCAR DISABILITIES

On the Dorsum of the Hand —This is the common location of disabling burn scars. Their severity may be graded as follows —

SCARS WHICH LIMIT FLEXION OF THE METACARPO-PHALANGEAL JOINTS — Gillies has used the term invisible skin loss for the reduction of that excess of skin area and mobility which is needed for free flexion of the hand It may only be manifest by tightness and abnormal blanching over the knuckles when the metacarpo-phalangeal joints are flexed (Fig. 197)



FIG 197

Tightness and blanching over the knuckles after a dorsal burn

This indicates some degree of skin loss despite an apparently full flexion range.

It must not be supposed that second-degree burns even if they heal in optimum fashion do not result in residual fibrosis and contracture Though healing occurs from the islets of undestroyed epithelium it does so by the secondary intention process over the intervening areas of dermis which do not present epithelium to the surface This involves granulation and fibrosis, the extent of which depends on the size and number of the areas Thus, the

Too early relaxation from these principles of after-care is a potent cause of instability repeated breakdown and chronic ulceration

It takes many months for final resolution and softening to take place before the end result can be assessed

SECONDARY REPARATIVE SURGERY OF THE BURNT HAND

Most of the disabilities which persist after the healing of a burnt hand are *the effects of scar tissue All of them are at least associated with problems of*

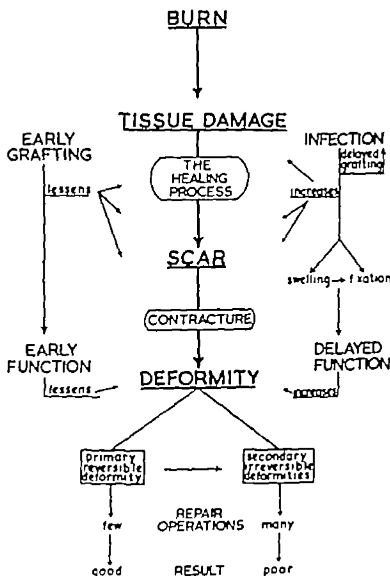


FIG. 196

Factors affecting the healing process of a burn.

scar The amount of skin loss and contracture and the period of its persistence are the chief factors which influence the severity of any residual handicap All that has been said in Chapter XII concerning scar disabilities has equal

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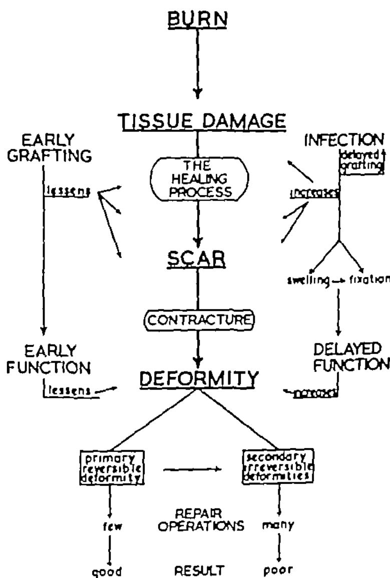


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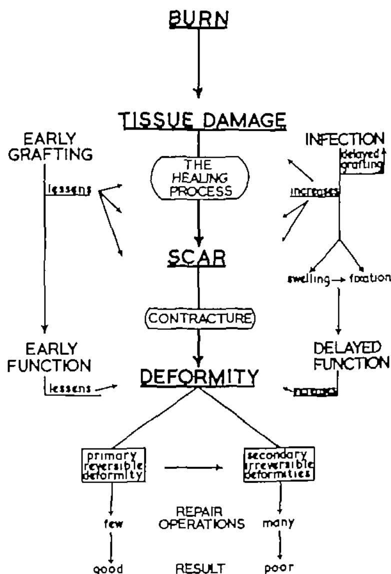


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deeper the burn the more secondary intention healing necessary and the slower the process, despite the fact that we are speaking only of burns of second-degree nature This may be the explanation of the prevalence of hypertrophic scars in deep second-degree burns.

Tightness cracking or instability and vulnerability to petty trauma may call for correction of invisible skin loss, but when there is only some limitation of joint range without joint deformity there is no urgency for this.

Where limitation of joint range is more marked, scar correction is *more* urgent because capsular contraction rapidly follows if the range is not increased by early release from the scar contraction effect These scars *usually* result from deep second-degree burns and they are frequently of a hypertrophic nature (*Fig.* 198)

SCARS WHICH INDUCE METACARPO-PHALANGEAL JOINT DEFORMITY —These result from still more severe and extensive burns generally of third degree,



FIG 198

Hypertrophic scar on the dorsum of the hand

This generally arises from burns of deep second degree where spontaneous healing has been slow and often retarded by infection. Skin loss, fibrosis and contracture limit function and the scars are intensely irritable.

which have slowly healed from their periphery They do more than limit function they induce deformity In time this causes secondary deformity in other joints, which may fast become irretrievable There is some urgency therefore for correction These scars produce a characteristic deformity (Fig. 199) with hyperextension of the metacarpo-phalangeal joints and flexion deformities of the interphalangeal joints This latter component is in some cases due to actual destruction of the central slip of the extensor expansion In addition to the effects of scar contraction in the long axis of the hand there occurs deformity and disability from contraction in the transverse axis. This causes tightening and traction on the volar skin which is pulled around the side of the hand frequently causing adduction fixation of the thumb through loss of the normal slack in the thumb web There is also a bunching together of



Fig 199

Characteristic deformities associated with an extensive dorsal burn

The finger deformities are generally worse on the ulnar side of the hand on account of greater mobility of the fourth and fifth metacarpals.

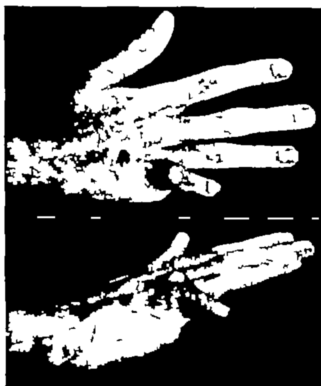


Fig 200

Typical deformities of little finger with a dorsal burn.

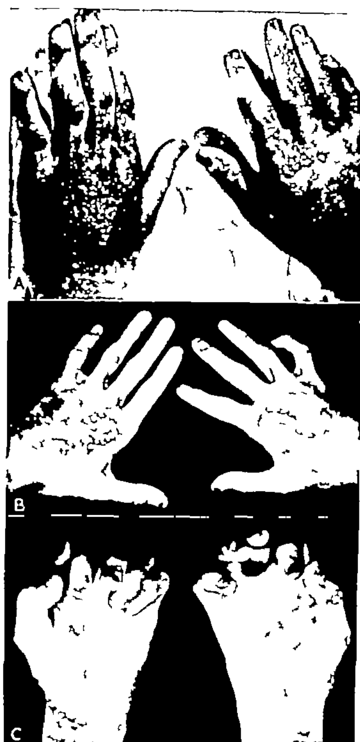


FIG. 201

Progress of severe dorsal burns of the hands, their scar contracture and its ultimate correction

A, Unhealed third-degree burns of hands and fingers resulting from an aircraft accident.
B, The healed result—palliative pinch grafts were used.
C, The maximum flexion permitted by the dorsal scarring and fixation.

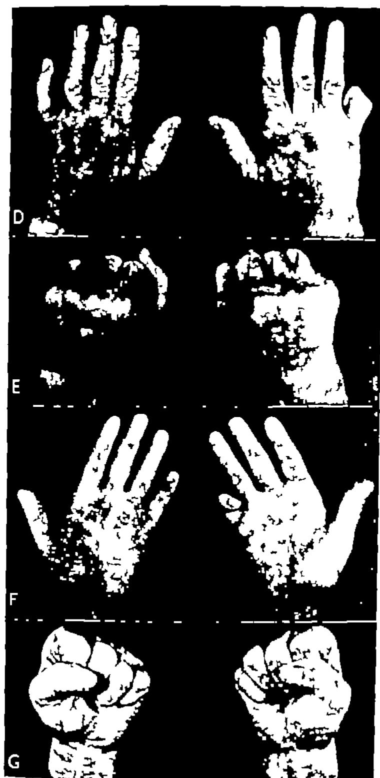


Fig 201

Progress of severe dorsal burns of the hands, their scar contracture and its ultimate correction

D, E, F, G, Indicate the final result after replacement of dorsal scars by thick split-skin (dermatome) grafts and the volar scars by whole-skin grafts (Wolfe).

(*Medic l War History*)

the metacarpal heads with loss of the normal transverse palmar arch and backward displacement of index and little finger metacarpals.

These deformities are usually more marked on the ulnar side of the hand, the ring and little fingers showing exaggeration of hyperextension (Fig. 200). Secondary fixation of the extensor tendons with obliteration of their normal gliding planes and surfaces contributes to the disability

HYPERTROPHIC DORSAL SCARS—Any of the above scars may be hypertrophic and irritable It is a paradox that the deeper burns and more deforming scars are generally not so hypertrophic as the scars resulting from deep second-degree burns This scar hypertrophy is exactly analogous to the scar on the donor sites of grafts cut deeply with the dermatome It should not be regarded as keloid

Correction of Dorsal Scars—Creation of the basic defect by scar excision and dissection and correction of this by skin replacement are the objects of

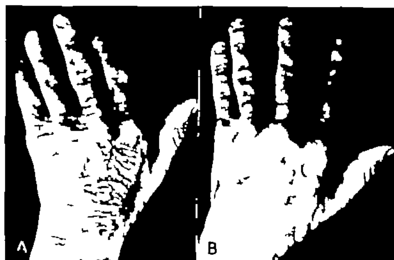


FIG. 202

Split-skin graft for dorsal burns

A, Shows residual skin loss and tightness following a burn.
B, Nine months after scar excision and a thick split-skin graft cut with the dermatome.

treatment The latter is best achieved by a thick split skin graft (Figs 201 and 202) unless a flap is required for subsequent tendon reconstruction

Scar excision must be liberal The edges should be arranged for optimum line of marginal scars. In some cases this might involve removal of small areas of normal skin while in others it might be of advantage to leave certain areas of scar which are benign in their effect. There is a practical limit to the area of scar which should be excised at one operation It is often safer and therefore quicker in the long run to stage a scar replacement if it extends to places about the sides and front of the hand or if all the dorsal aspects of the fingers are involved In this case it is better not to carry the dorsal hand dissection beyond a line just proximal to the first interphalangeal joints

The scar is stripped off the plane of deep fascia enveloping the extensor tendons, without baring the tendons of their paratenon. Dissection must be done with some restraint, realising that ideal correction cannot always be obtained. The temptation to complete correction by any forceful stretching or manipulation must be resisted. A tourniquet must be used during this part of the operation. It is removed for careful hæmostasis. In some cases if ooze persists, and if a long tedium is envisaged for adjustment of a skin graft, the tourniquet can be reapplied until the pressure dressing has been arranged.

An evenly cut split skin graft of about three-quarter thickness is in general the best graft for an extensive dorsal scar replacement. It is cut most evenly with the dermatome. At least one drum (8 by 4 in.) is required—often more. This is best arranged transversely.

The hand and wrist are fixed in flexion to exaggerate as far as possible the surface extent of the defect, so that a greater area of new skin can be let in. Hæmatoma is the main factor conducive to failure and must be prevented by all refinements of technique (see Chapter V).

When postural deformities of joints are associated, their correction is frequently attempted at the skin replacement operation. Lateral capsulotomy of the metacarpo-phalangeal joints can be done with advantage through the open defect. Dissection of the extensor expansion in the region may be indicated despite some extra risk to the successful take of the graft. Here, again, the optimum correction is not the maximum correction if this involves forceful manipulations and baring of deep structures.



FIG. 203

Contractures from a volar burn

Gross deformities may arise without destruction of essential structures. The fingers are fused on themselves and into the palm. The scarring involves only the skin and subcutaneous tissue.

Secondary grafts should be applied to missed areas of the primary graft as soon as the base is adequate.

Second-stage operations if indicated are done after a fair interval to assess the value of a first operation and allow a period of hand function. Separate adjustments in the region of the finger webs may be needed. To these regions the "Z" principle can frequently be applied with advantage—otherwise separate small grafts on pressure moulds improve the quality of the result.

Flaps may be needed for replacement of deeper scars for more severe burns. There must be proper adaptation of margins of scar excision to the design and dimension of any direct flap which is used.

Palmar Scar Contractures.—Flexion contractures are frequently the ultimate manifestation of severe contact burns of the palm, and they are more frequently seen in children. In contrast to the scars resulting from dorsal burns,

palmar scars must be much deeper to involve essential structures. The thickness of skin and the more liberal bulk of soft tissue permit of more extensive burns more scar contracture and finger flexion deformity without damage to tendons and nerves. It is not uncommon for fingers to be completely fused by scar in the flexed position (Fig. 203) and yet dramatic results can still be obtained by replacement of the volar skin There is not the same urgency to relieve such scar contracture as in the case of dorsal scars.

Correction of Palmar Scars—The essentials of technique in no way differ from the case of dorsal scars except that for reasons described on page 93 more frequent use is made of Wolfe grafts (Fig. 204) Thick split-skin grafts are reserved for the larger areas



FIG 204

Localised burn scars on the fingers

Few are amenable to correction by "Z" plastic and most require whole-skin grafts. A, Long-standing scar contracture, result of a burn in childhood. B The result following whole-skin grafts.

After scar dissection the limit of finger extension in cases of long-standing deformity especially those initiated in childhood, is conditioned by the bow stringing effect of the digital nerves across the proximal finger crease region. This limitation must be accepted at least for the time being. Further extension is sometimes feasible after a period of use and function.

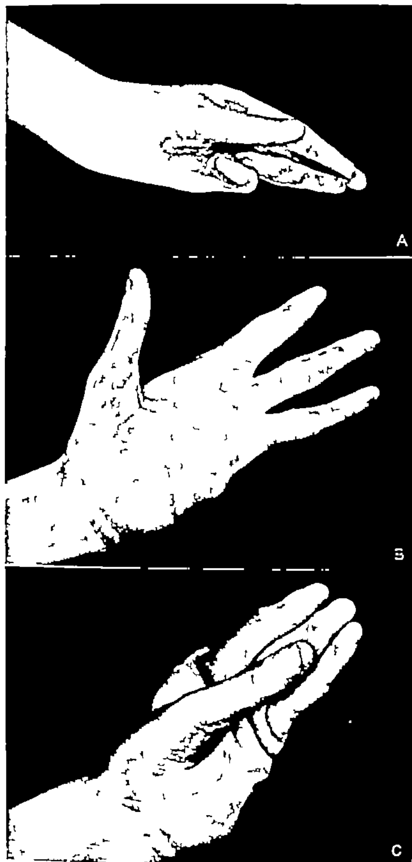


FIG 205

Deep palmar scars

A, The result of injury in a steam press after healing was completed with aid of palliative split-skin grafts. The whole of the palmar skin was lost and there was exposure and sloughing of portions of the flexor tendons to all fingers.

B C, The result three years after completion of a programme of volar skin replacement by migration of an abdominal tube pedicle supplemented by free graft in the thumb web.

LOCALISED SCARS ON THE FINGERS AND WEBBING DEFECTS.—Linear scars and webbed scars can often be corrected by "Z" rearrangements, provided it is recognised that free grafts must be used to supplement flaps which cannot cope with the total defect.

DEEP SCARS INVOLVING TENDON OR NERVE DESTRUCTION —In most of these cases flaps are required to correct the defects whether or not subsequent tendon or nerve repair is envisaged (Fig 205)

The principles and methods of secondary reparative work relative to tendon nerve or bone are exactly those as described in Chapter XIII

Fixed Joint Deformity —Joint deformities which cannot be corrected by scar replacement or by secondary soft tissue procedures may call for permanent

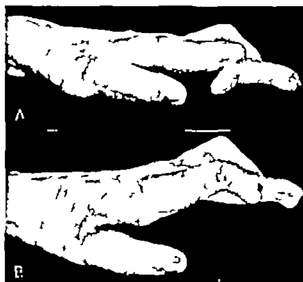


FIG. 206

Arthrodesis for joint deformities

With destruction of the extensor system and disorganised joints only arthrodesis will relieve the acute flexion deformities which develop in inter phalangeal joints.

A, Acute flexion deformity at the proximal inter phalangeal joint of the index finger

B, After joint excision and fixation in partial flexion.

fixation in a more useful posture. Thus arthrodesis of interphalangeal joints is sometimes done by joint excision and plaster or pin fixation (Fig. 206). In other cases amputation of a finger or part of a finger will contribute more to the general use and function of the hand This especially applies to the little finger

Nail Deformities —In extensive dorsal burns, finger flexion is permitted only against the tightness and taut [illegible] limited area of [illegible] This is often manifest in a pulling bac[illegible] skin from over [illegible] of the nail bed and irregular overgr[illegible] nail It can only [illegible] by the general procedures directed [illegible]

CHAPTER XVII

HAND INJURIES IN CHILDREN

GLASS or knife cuts contact burns and the varied results of meddlesome interference with domestic machinery account for the vast majority of hand injuries in childhood The general principles enunciated concerning the surgery of injury apply to patients of all ages, but there is a sufficient number of variants in their application to children to warrant some special discussion.

HEALING TIME AND THE BEHAVIOUR OF SCAR

Apart from an innate capacity for rapid healing in the young, which is seen in relation to every tissue throughout the body there are certain mechanical factors which differ from one age group to another in comparable injuries These are probably the most significant features in the rapidity of healing in children following tissue loss or destruction The absolute surface area and depth of tissue involved in injuries of the palmar surface of hand and fingers are several times greater in adults than in young children and even if the rate of repair were the same in both cases the child s hand would be healed much sooner Indeed in the treatment of burns although one may have the best of intentions for grafting the surface as soon as slough is declared and separated, spontaneous epithelialisation from the edges covers the small surface area so quickly that healing is often complete by the third or fourth week and little opportunity for grafting arises.

Despite this rapidity in healing however, the mechanism does not vary, except that the quantity of deep scar which results from long-continued granulation in adults is much reduced in children and resolution and softening are correspondingly quicker The scar passes through the same phases of contraction and often hypertrophy and the effects of surface scar contractures on joint posture and mobility are exactly the same as in adults where the area involved is comparable relative to the hand as a whole Once established scar contracture persists throughout life, and although in time its effects may be minimised by slow stretching of the adjacent soft tissue, we have seen little evidence of any regional increase in rate of growth to make good the defect Time and growth do not preclude the necessity for secondary replacement of the tissue that has been lost.

CAPACITY FOR REMODELLING AND DIFFERENTIATING TISSUES

This capacity which is perhaps given more prominence in regard to repair following fractures seems to exist also in soft tissues in babies and young children. It probably accounts for most of the superior results of reparative operations in children as compared with adults, and means that certain modifications in procedure are necessary This applies particularly to flexor

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DEEP SCARS INVOLVING TENDON OR NERVE DESTRUCTION.—In most of these cases flaps are required to correct the defects whether or not subsequent tendon or nerve repair is envisaged (Fig. 205)

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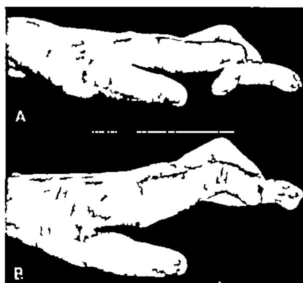


FIG 206

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A, Acute flexion deformity at the proximal inter phalangeal joint of the index finger

B, After joint excision and fixation in partial flexion.

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Nail Deformities.—In extensive dorsal burns, finger flexion is permitted only against the tightness and taut effect of a limited area of dorsal skin This is often manifest in a pulling back of the distal skin from over the region of the nail bed and irregular overgrowth of the nail It can only be alleviated by the general procedures directed to skin replacement.

The same applies to severed nerves, where the rapidity and completeness of regeneration following careful primary repair are a constant source of wonder when compared with the results of similar injuries in grown ups (Figs 208 and 209) Even if delayed repair in adult nerve injuries were sound—and we

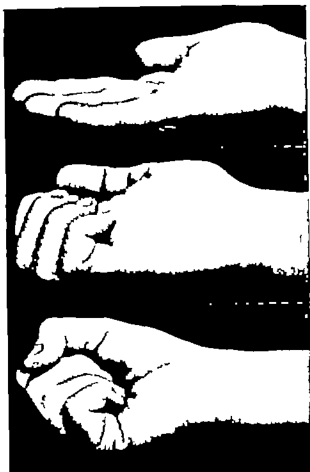


FIG. 209

Primary repair of tendons and nerves in the proximal palm in a child of 8 years

Both sensory and motor branches of the ulnar nerve were sectioned just distal to the bifurcation of the nerve. The flexor tendons to middle, ring and little fingers were also divided. The flexor profundus tendons to the affected fingers, together with both branches of the ulnar nerve, were repaired primarily Sensory recovery in the ring and little fingers had extended to the finger tips by the end of three months, by which time motor recovery was also well advanced. At the end of six months the only residual disability in the hand was some weakness in adduction of the little finger

have disputed this—there could be no justification whatever for its application to children. The principle of primary repair of all divided structures, wherever the local and general conditions permit, is one which has no exception when dealing with hand injuries in young children

THE BEHAVIOUR OF GRAFTED TISSUE DURING GROWTH

There is surprisingly little information recorded on this subject, but from simple clinical observation we have seen nothing that would lead us to believe

tendon repair Though we have made a regional exception to the principle of primary repair in tidy wounds in the case of tendons severed within the digital

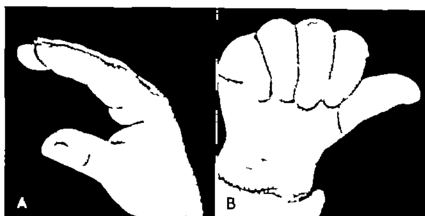


FIG. 207

Primary repair of flexor tendon in the finger in a child of 3 years

Both tendons were divided by glass cut over the proximal phalanx of the index finger of a child aged 3 years. The flexor digitorum profundus only was repaired at primary operation. A and B show the order of active flexion one year later

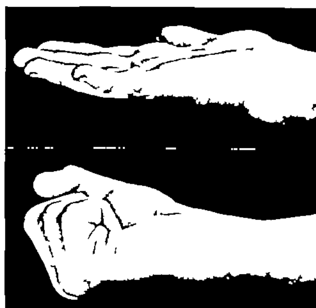


FIG 208

Primary repair of tendons and nerves at the wrist in a child of 10 years

Both median and ulnar nerves were sectioned together with the flexor tendons to index, middle, ring and little fingers. The flexor pollicis longus was intact. All structures were repaired primarily Sensory recovery had extended to the tips of all fingers at the end of three months and by this time motor recovery was also well advanced. At the end of six months the only residual disability in the hand was weakness in adduction of the little finger

theca, such an exception cannot be justified in small children up to about 5 years of age. The results of direct primary repair in the fingers, provided only the profundus is sutured are far more satisfactory than in adults (Fig 207)

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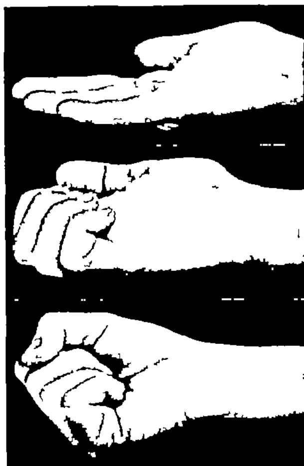


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THE BEHAVIOUR OF GRAFTED TISSUE DURING GROWTH

There is surprisingly little information recorded on this subject but from simple clinical observation we have seen nothing that would lead us to believe

that the rate of growth of grafted tissue differs appreciably from the normal Recurrence of deformities and apparent progressive inadequacy of a graft are invariably to be explained by the contraction of badly placed marginal scars, or scars which represent "missed" areas of the graft These effects develop early if they are going to occur and it can be asserted that if the size of a graft

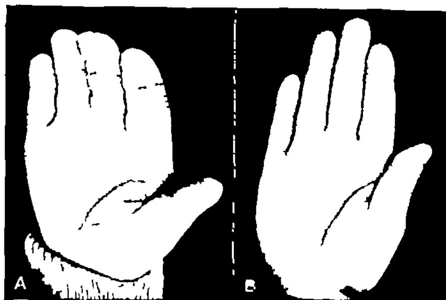




Fig 210

The growth of skin grafts

A, Shows a large Wolfe graft over the distal palm and proximal portion of all fingers for gross scar contracture following contact burns. There was no limitation in finger movement at this time.

B, The same hand two years later The whole hand has increased greatly in size during this period of growth. So, too has the area of the graft and there is still no limitation of the range of finger movement.

C, The same hand after another five years. The graft bears the same relationship to the hand as a whole and clearly the rate of growth has been no different from the rest of the hand skin

whether it be skin tendon or other tissue, is adequate for a full range of movement when scar resolution is complete, it will remain so throughout life. It will retain its same proportionate size relative to the hand as a whole throughout the growth period (Fig. 210) We must be clear however that this will apply only to grafts which remain viable, gain an adequate blood supply and become incorporated as part of the body structure "Grafts" which are not viable when introduced or which die *in situ* and fail to become incorporated

in the body will be either extruded, absorbed or retained as inert foreign bodies A graft must never be regarded as a parasitic entity complete in itself If these principles are accepted then it is clear that a successful graft can have no independent growth rate or behaviour A clear understanding of these basic ideas is important in dealing with children s hand injuries which are associated with soft tissue loss, or when the sacrificing of irreparable structures and graft replacement are necessary to restore function There is no age limit in considering methods of soft tissue replacement. The only factors which vary with age are the size of the structures involved and the degree of understanding and co-operation by the patient. These introduce special problems of operative technique and of management, but most can be solved without much difficulty The results of surgery are usually much superior to those obtained in comparable procedures on adults.

INTERFERENCE WITH JUXTA EPIPHYSEAL GROWTH

Despite these observations concerning the results of soft tissue repair and replacement, we must never lose sight of the late effects of injuries which involve the epiphyseal lines of bones. Despite the most perfect result of primary repair methods in these regions, premature or irregular fusion of the epiphysis may result in a progressive deformity in the years that follow Little can be done to avert this, and such developments can only be treated on their merits as they arise, with due regard for the additional effects on growth of any further surgical intervention A long term plan is essential in all such cases and many corrective operations will need to be delayed until these regional growth factors are no longer operative It goes without saying that no secondary operations on bones or joints should be undertaken in childhood without a full understanding of their implications on subsequent development. Such considerations are, however confined to the skeleton and it is indeed fortunate that we need have no such fears in relation to the soft tissues of the body

DIFFICULTIES OF DIAGNOSIS

The older child can often give a clear and dispassionate account of his injury He will submit readily to detailed examination unmoved by the fears for the future and the mental shock which cloud the adult mind In younger children however we have to rely on an uncertain history from a distracted parent and our own objective examination Subjective tests for tendon and nerve injuries are useless and confusing in the early years

Nowhere is a full appreciation of the normal hand posture and of normal tendon tension more important than in the diagnosis of tendon injuries in small children. There is no need to lay a hand on the child to get all the pre-operative information that is required The extent of the surface injury together with the mechanism and direction of the injury will indicate at once what deep structures are suspect The child is then comforted by the nurse and may soon

fall off to sleep When quiet, the hand is simply observed in the position in which it lies, and every variation from the normal posture is carefully noted. Finally if any doubt still exists, *light pressure* on each finger tip in turn will enable an assessment of tendon tension both flexor and extensor Errors in diagnosis occur when attempts are made with a struggling, crying child to assess the degree of *active finger movement* of which the child is capable.

There is no accurate confirmatory test for nerve injury in such children If the course of a nerve is related to the surface wound and direction of injury, the nerve must be presumed to be cut until its continuity is demonstrated at operation

IMMOBILISATION

We have been at pains to stress the necessity for complete immobilisation *until sound healing is assured* The application of this principle to hand and finger injuries in babies and children of " toddler " age may tax a surgeon s ingenuity and patience to the limit. Babies may acquire an almost complete range of finger movement within a day or two inside a plaster which appeared adequate. Older children may bend break or saturate their plasters, despite ordinary parental care, well inside the time limit set for adequate fixation. Little harm comes from this in simple soft tissue wounds but in tendon repair it spells disaster The difficulties can only be overcome by a great deal more than ordinary care in plaster technique, immobilisation of the whole hand and forearm as well as the particular finger or fingers concerned and constant personal supervision by the surgeon throughout the post-operative period Even greater use may be made than in adults of an exaggerated wrist posture to keep repaired tendons slack The capacity and willingness of parents to watch over their children in this stage must be carefully assessed before allowing the child to go home They must be carefully briefed as to what is required of them and the consequences of neglect. Simply to discharge a patient from hospital with a note to attend an out patient clinic in one, two or three weeks is to court trouble

TECHNICAL DIFFICULTIES IN REPAIR

As in all aspects of children s surgery these difficulties are related to the size of the part and of the individual structures Fine instruments and a gentle hand are indispensable. The hand stand and attachments (Fig. 25) are particularly valuable, for there is no room for assistant s hands. The armamentarium previously described (p. 41) needs little modification except in regard to needles and suture materials used in tendon and nerve repair In children up to about 3 or 4 years of age we use a very fine waxed silk (No 6/0) for this purpose Beyond this age the size and strength of suture material for tendon repair can be increased, and for children about 10 years we use the same materials as for adults.

A great deal of patience is needed in operating on these small structures in children but no time must be wasted We may take hours over an extensive

tendon and nerve repair in an adult, but while older children will tolerate this equally well babies cannot safely be subjected to such lengthy procedures. Fortunately there are few problems of bleeding and the area of dissection, exposure and suturing is less. Even so, only an experienced and deft operator will be able to do all that is necessary in the short time that is available to him

Despite our insistence that all divided structures in babies and very small children be repaired primarily whenever the conditions will permit, there will always be a few cases where this has not been done and where too long a period has elapsed for secondary direct repair of tendons to be practicable In these cases tendon grafts will be necessary just as in older children and adults, but owing to the small size of the structures they can be much more difficult. Under these circumstances the palmaris longus which is normally the first choice for a free tendon graft following flexor tendon injuries is so small and thin that we prefer to use the remaining length of the flexor digitorum sublimus as the graft. This is a much better tendon for the purpose in children, and the objection to its use in adults which is based upon its size and the risk of central necrosis does not hold at this early age.

CARE OF DRESSINGS AND REMOVAL OF SUTURES

Constant supervision of dressings and adjustment of bandages and splints are extremely important The standard of care in the maintenance of surgical dressings in a children s ward is a reliable guide to the quality of its nursing staff The use of a sling which not only supports the forearm but also is sufficiently voluminous to be folded and pinned in such a way as to enclose the whole arm and hand completely is invaluable Both in the ward and after discharge this is maintained in position constantly and the parents are instructed as to the absolute necessity of its continued maintenance in position at home and in between hospital visits

It is not always easy to predict how a child will respond to dressing changes and removal of sutures, particularly between the ages of 2 and 6 years Before this there is invariably some crying and struggling In older children confidence is easily gained, and there is rarely any great difficulty In simple uncomplicated soft tissue wounds a little struggling is of no account, but when grafts are being dressed in their early stages, or when sutures and plasters are being removed following tendon and nerve repair such a struggle may put a swift end to any prospect of success and may wreck in a moment the work of weeks. In small or unco-operative children therefore, these procedures require a general anaesthetic Dressings are left undisturbed for as long as possible and sutures are left until healing is complete, so that only one anaesthesia is needed for this purpose. Following tendon repair it is our practice to leave dressing and plaster undisturbed for four weeks. The plaster is then cut off and the sutures removed under anaesthesia and all dressings and restraint are discarded Older and more co-operative children can be managed in the same way as adults.

INTERMEDIATE TREATMENT AND PHYSIOTHERAPY

In children under 4 or 5 years there are few problems of intermediate management which are not spontaneously solved over the course of a few

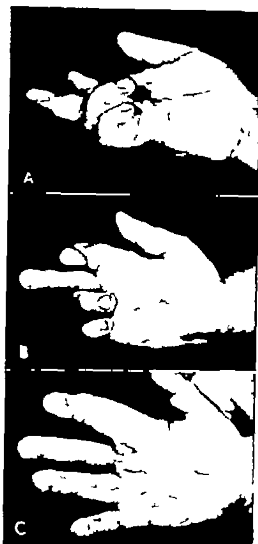


FIG 211

Result of scar correction by Wolfe grafts after long outstanding contracture and joint deformity

A and B, Show the degree of contracture following contact burns to the palmar surface of hand and fingers.

C, Shows restoration of a full range of finger extension after replacement of the scar by Wolfe grafts despite a delay in treatment of two years.

months. The constant and instinctive efforts at movement in all joints in an attempt to put even the most extensively injured hand back into use by a child who is oblivious to the effects of injury make any form of physiotherapy seem futile by comparison Unless a joint itself has been the subject of direct injury we need never fear secondary joint changes in children to the extent

that we do in adults Relief of scar contractures will nearly always be followed by recovery of a full range of joint movement even though years have elapsed since injury (Fig. 211)

Apart from the preliminary replacement of surface scar to permit repair of deeper structures, we can generally proceed direct to any secondary reparative work after the lapse of sufficient time for scar resolution following injury

RECOVERY AND RE-EDUCATION

The degree and speed of functional recovery after hand injury in children is due not only to rapid healing and a capacity for regeneration and differentiation but also to a remarkable faculty for re-education A child may learn to use a transplanted muscle in a new way within a day or two and to a degree of perfection which would take weeks or months in an adult. Every possible variety of 'trick movement is rapidly acquired to compensate for the effects of nerve lesions, and it may be that the extraordinary speed and completeness which characterises motor regeneration at this age is at least in part due to an increased capacity to rearrange the central pathways of peripheral axones.

These factors serve particularly to emphasise the necessity for the utmost conservatism in the management of hand injuries in early years The growing child will find a use for every element of its hand that is left to it, irrespective of any ideas that surgeon or parent may have concerning the value and appearance of the remnant. Prosthetic aids are of little help and, indeed rarely necessary except in bilateral amputations

CHAPTER XVIII

HAND PROSTHESIS

NO man made mechanism has reproduced or ever will reproduce any functioning semblance of the human hand The general inadequacy of hand prostheses underlines the importance of utmost conservation whenever hand amputation is under consideration Any degree of normal hand feeling or usefulness which can be salvaged or made effective by surgical operation (as indicated in Chapter XV) is so far preferable to any artificial hand that no thinking surgeon could but err on the side of conservatism in the primary treatment of gross hand injury

Upper limb amputees are rarely seen wearing any kind of hand prosthesis. Many more limbs are supplied than are ever used This again emphasises their general ineffectiveness.

There is no end to the form of hand substitutes which have been devised and tried through the years the world over None, of course, can serve any sensory function Most fail badly from the æsthetic or social standpoint Functionally however worth-while help is derived from many interesting mechanisms which have been used Some of these are of an entirely passive nature—simple utilitarian devices attached by clips or slots to forearm buckets (Fig. 212) Some are of an active nature, indirectly activated in crude but often effective degrees of simple function from the muscles of the same or opposite shoulder The cleft hook is a well-known example of this type. Such prostheses have been of great benefit to individuals, but the overall picture is not a happy one.

Cineplasty

In comparison with any indirectly activated mechanism, cineplasty involves utilisation of the muscles in an amputation stump to activate a prosthesis. This principle has been little developed or applied in British countries Full details of local development of the method are set out elsewhere.[1] If a socially presentable standard of æsthetic result is combined with the order of movement and function which cineplasty permits, properly selected patients will continue to wear a forearm prosthesis of this type The limitations of the method are not in the preparation of stable skin-tubes through the activating muscles. This can be achieved by carefully designed flaps and we have shown that it can be carried out in a one-stage procedure at the time of a forearm re amputation (Fig. 213)

The limitations of the method are in the perfection and manufacture of a sufficiently sensitive delicate and durable mechanical prosthesis of sufficient æsthetic merit A prosthesis of the type illustrated (Fig. 214) involves much individual time and skill in its construction We have not been able to produce it for more general application

[1] Rank & Henderson (1946) Cineplastic forearm amputations and prostheses *Surg Gynec Obstet* 83 373



Fig 212
Passive forearm prosthesis used with much effect by a bilateral forearm amputee.



FIG. 213

Cineplastic amputation

A, Before re-amputation.

B, C, Dorsal and volar aspects three months after a one-stage operation for re-amputation and construction of skin tubes from flaps designed along with the amputation flaps from the distal forearm.

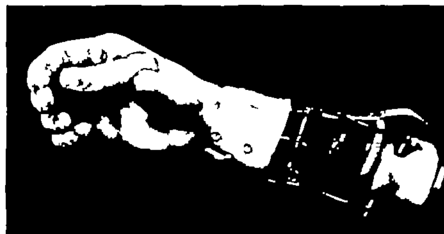


FIG. 214

Cineplastic prosthesis shows the high standards of construction and appear ance which can be achieved by modern methods and materials—as yet not fully exploited to this purpose

BICEPS CINEPLASTY

In recent years biceps cineplasty for forearm amputation has been more extensively developed and used by a number of American surgeons One of our associates, Mr J T Hueston [1] has applied and demonstrated the particular advantages of this procedure in well selected cases It involves using a cineplastic motor in a limb segment proximal to the amputation region

After a routine of physiotherapy to build up and educate the biceps muscle as a separate unit, a skin tube tunnel is constructed through the distal portion of the muscle after its tendon is detached from its insertion (Fig 215) Only

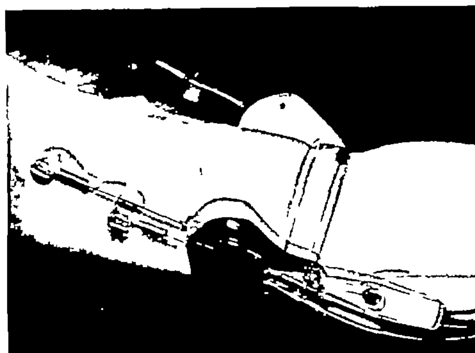


FIG. 215

Double exposure photograph taken with the biceps contracted and relaxed showing the range of movement and how it is transmitted by a Bowden cable to activate the prosthesis.

(*Reproduced by permission from Aust and N.Z. Journal of Surgery Vol XXVIII No 4 pages 8 and 284 —J T Hueston*)

the one tube is made and this can motivate a simple more standard and substantial type of prosthesis with impressive effect (Fig. 216) The biceps contraction can be used either for voluntary opening or voluntary closing of a simple cleft hook or a more æsthetic hand attachment and these can be interchanged on the same prosthesis.

The particular advantages of the biceps cineplasty are the power and range which can be achieved It can be built up to a pull of 50 to 80 lb through an excursion of 2 to 2½ in This permits of simplicity in fitting and manipulating a cleft hook mechanism and if the muscle contraction is used for voluntary closing some proprioceptive sense can be acquired in the skin tube

[1] Hueston, J T Biceps cineplasty for forearm amputees. *Aust N.Z J Surg* May 1959 28 No 4 280-285

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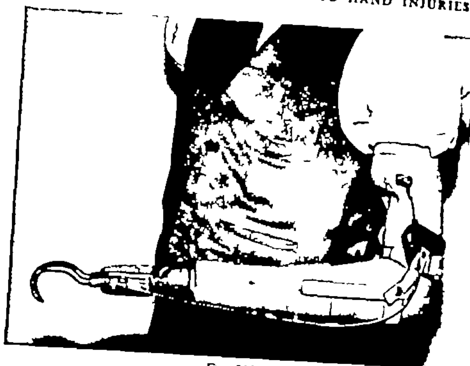


FIG. 216

Biceps cineplasty can be used to effect either voluntary opening or voluntary closing of a cleft-hook prosthesis.



FIG. 217

A bilateral amputee with biceps cineplasty and voluntary closing cleft-hook type prosthesis. He demonstrates finesse of manipulation. With voluntary closing there is also some proprioceptive sense

(Reproduced by permission from A... and N.Z. Journal of Surgery Vol. XXVIII, N... [illegible] ... and ... J. T. Hue...)

The absence of a shoulder harness makes for a vast improvement on standard cleft hook arrangements with more comfort and freedom of movement In the case of bilateral amputees there is complete independence of each limb (Fig. 217)

PECTORAL CINEPLASTY for upper arm prosthesis has not yet reached a stage of development for general application to upper arm amputees

It is unfortunate that many arm amputees and their relatives are easily and often led astray by wild claims or talk of the miraculous. In face of this the surgeon must deliberately and carefully advise his patient in terms of the cold practical reality of what is available to him There are two decisions —

1 *Should a prosthesis be fitted at all?* It does not necessarily follow that every forearm amputee should be fitted with a prosthesis One has only to see the degree of confidence achieved with a forearm stump by childhood or congenital amputees to realise that many could not be helped by any mechanical appliance Others including the elderly cannot reasonably be expected to learn the use of an appliance which necessarily takes much time, patience and application Occupation intellectual calibre and psychological adjustment to disability and deformity all influence the case for forearm prosthesis—the decision may be for or against. What a patient expects of prosthetic aid must be weighed against what really can be accomplished

2 *What type of prosthesis will best serve the particular case?* With factors already indicated the site and condition of the amputation stump are also important in this decision it may or may not be suited to a particular appliance or plastic operation it may or may not be possible to alter it.

Those most concerned with gaining maximum self help in the daily personal routines of life without expecting to achieve feats of brawn or strength are best helped by a simple type of bucket with attachments selected for their needs Those concerned with their livelihood as labourers or artisans need the help of stronger mechanical devices such as the cleft hook The "white-collar" man in sedentary occupation is concerned with a socially presentable appearance and some manipulative ability For him, cineplasty has its place, and this approach is not incompatible with alternative use of passive devices for special needs or perhaps a cleft hook for his gardening.

The bilateral amputee raises special problems which must be answered for the individual case Passive attachments cineplasty or various other mechanical arms, each have their advantage for particular cases

Finally it cannot be overlooked that many people are concerned only with the cosmetic camouflage of something which becomes objectionable to them The use of modern materials and methods has made great strides. In this direction we are now able to make many hand amputees, especially women happy and well adjusted citizens. There is no excuse to-day for tendering a crude glove-covered article as the best available æsthetic counterpart for a hand If this aspect alone of the requirements of hand prosthesis is answered by skilful use of modern materials, many more patients will be interested in obtaining and continuing to wear some artificial hand or fingers (Figs 218 and 219)

Amputation in Relation to Hand Prosthesis

The so-called site of election for forearm amputation has been *elaborated in relation to standard prosthetic arrangements.* It should not be applied universally Conservation of maximum forearm length may be better for many If cineplasty is anticipated a longer stump can always be reduced

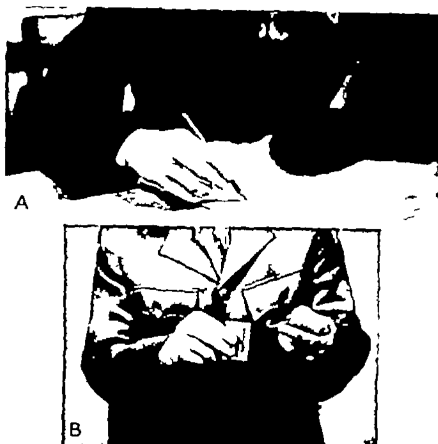


Fig 218

Cosmetic standards of hand prosthesis

Comparative standards in appearance of what is commonly supplied and what can be done in hand prosthesis.

A Bilateral amputation with cineplastic prosthesis on right hand and normal dress arm on the left side.

B, Unilateral amputation with cineplastic prosthesis.

when the cineplastic operation is done In some cases distal skin may be of value in relation to skin tube construction Furthermore when it is unlikely that any prosthesis will be fitted or used especially with those in sedentary life maximum forearm length may be more useful and comfortable for general leaning and steadying purposes We have seen little evidence of the relative *circulatory deficiency* of long forearm stumps which is often erroneously used as an argument in favour of standard proximal forearm amputations





FIG. 219

Prosthetic substitutes for complete hand loss have a place for occasional use in particular cases. They can be made in light construction of a very high æsthetic standard.

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